THE DECEMBER SCIENTIFIC MONTHLY

EDITED BY J. MCKEEN CATTELL

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THE SCIENTIFIC MONTHLY

DECEMBER, 1937

OUR SAMPLE OF THE UNIVERSE

By Dr. EDWIN P. HUBBLE

ASTRONOMER, MT. WILSON OBSERVATORY

The Observable Region of Space

Our sample of the universe is the region of space that can be explored with existing telescopes. The observable region is defined by the largest telescope available, and, in our generation, that telescope has been the 100-inch reflector at the Mount Wilson Observatory of the Carnegie Institution of Washington.

It was the 100-inch reflector which pushed out beyond the boundaries of our own stellar system and found other stellar systems—the nebulae—which are the true inhabitants of space. The nebulae had long been observed as mysterious patches of light strewn among the stars. Now, with their nature established, they are recognized as gigantic beacons scattered through the depths of space. The nearer nebulae appear large and bright; the more remote nebulae, small and faint. They can be followed on and on until they dwindle to mere specks and then vanish completely.

The vanishing point—the last horizon—is immensely distant. On photographs with the 100-inch, nebulae can still be recognized when they appear about two million times fainter than the faintest star that can be seen with the naked eye. Yet these specks are the images of great stellar systems which average about 200 million times as bright as the sun. In order to appear so faint, they must be so distant that light travels for 500 million years to make the journey. Thus the observable region of space, as defined with the 100-inch reflector, is a sphere about 1,000 million light years in diameter. This sphere, it is estimated, contains about 100 million nebulae, each a stellar system comparable with our own system of the Milky Way.

The nebulae are scattered irregularly; there are isolated nebulae, groups and, occasionally, great compact clusters. Nevertheless, a preliminary reconnaissance has shown that, when very large volumes of space are compared, the irregularities tend to average out, and the distribution approaches uniformity. On the grand scale, the observable region of space is very much the same everywhere and in all directions.

The preliminary evidence of uniformity suggested that the observable region might possibly represent a fair sample of the universe at large. As long as our knowledge was confined within our own stellar system, the possibility did not exist. The universe, we knew, was not filled with stars. But now the explorations have penetrated beyond the Milky Way. Our sample of the universe has been suddenly magnified a million, million fold. We study a vast region of space populated with stellar systems, and the region appears to be homogeneous. There is not the slightest evidence of a super-system of nebulae isolated in a

larger world. It is quite possible that any other large region of the universe, selected at random, would be rather similar to the particular region we explore with our telescopes.

Of course, we can not be certain. We do not know what lies beyond the limits of our telescopes. But the possibility exists, and it offers a welcome relief from sheer speculation. It justifies an attempt to infer the nature of the universe from the observed characteristics of the sample available for inspection. This attempt has been called the observational approach to cosmology.

The Problem of Cosmology

The reconnaissance had revealed two general features of the sample, namely, the roughly uniform distribution of the nebulae, and the roughly linear law of red-shifts in nebular spectra. These two characteristics, together with the general laws of nature, were all the information we had to guide the investigation of the structure of the universe. Therefore, the first step in the venture was to follow the reconnaissance with accurate surveys extending out to the practical limits of reliable measures with the 100-inch reflector. The limits are somewhat less than the extreme range of the telescope, but the outermost fringe had to be sacrificed in the interests of precision. The surveys added no new features to those already available, but they formulated the latter in precise numerical terms.

A careful examination of the results has led to two conclusions. In the first place, the observational data alone are not yet sufficient to completely describe the universe as a whole. Many possible types are ruled out, but a unique structure is not determined. In the second place, the law of red-shifts proves to be a vital clew, but the origin of red-shifts, an essential element in the interpretation of the clew, is still an open question.

The negative conclusions were inevitable. It was too much to hope that the structure of the universe would be revealed at this early stage in the development of scientific inquiry. Nevertheless, the first empirical attack has been remarkably successful in clearing the ground and orienting the problem. It might be said that a choice is presented, as once before in the days of Copernicus, between a very small finite universe and a universe indefinitely large plus a new principle of nature.

Alternative Interpretations of Red-Shifts

The new surveys permit us to reformulate the general features of our sample: the large scale distribution of nebulae is strictly uniform and the law of red-shifts is strictly linear, within the uncertainties of the investigations. The uncertainties are small but even so the greater part arises from the underlying uncertainty in the interpretation of the red-shifts. For this reason, the discussion of our sample will be introduced by an account of the appearance and behavior of red-shifts in nebular spectra.

Light from the nebulae is very similar to sunlight, and is a mixture of many different colors. With a prism, these colors can be spread out into an ordered sequence known as a spectrum. The rainbow, of course, is a typical example. A careful examination of the spectrum, either of the sun or of a nebula, indicates that certain colors are missing—that the sequence is interrupted by gaps or dark lines. The gaps represent colors that are absorbed by gases in the atmospheres of the sun or of the stars in the nebula. The pattern of dark lines identifies the actual gases—for instance, calcium vapor, iron vapor, hydrogen—and the precise normal positions of the lines are well known from measures in the laboratory.

In the sun, and the stars of our own

system, the lines appear about in their expected normal positions. In the nebulae, however, the lines are found out of place—more or less to the red side of their normal positions. These displacements are the red-shifts. They are conspicuous features in the spectra of all nebulae except a very few of our nearest neighbors. The amount of the displacement—the size of the red-shift—is found to be proportional to the distance of the nebula in which it is observed. The proportionality—the linear relation between red-shifts and distance—is known as the law of red-shifts. It is evidently an important clew to the nature of the universe, provided the clew can be correctly interpreted.

Actually, the interpretation of red-shifts is of fundamental importance, and

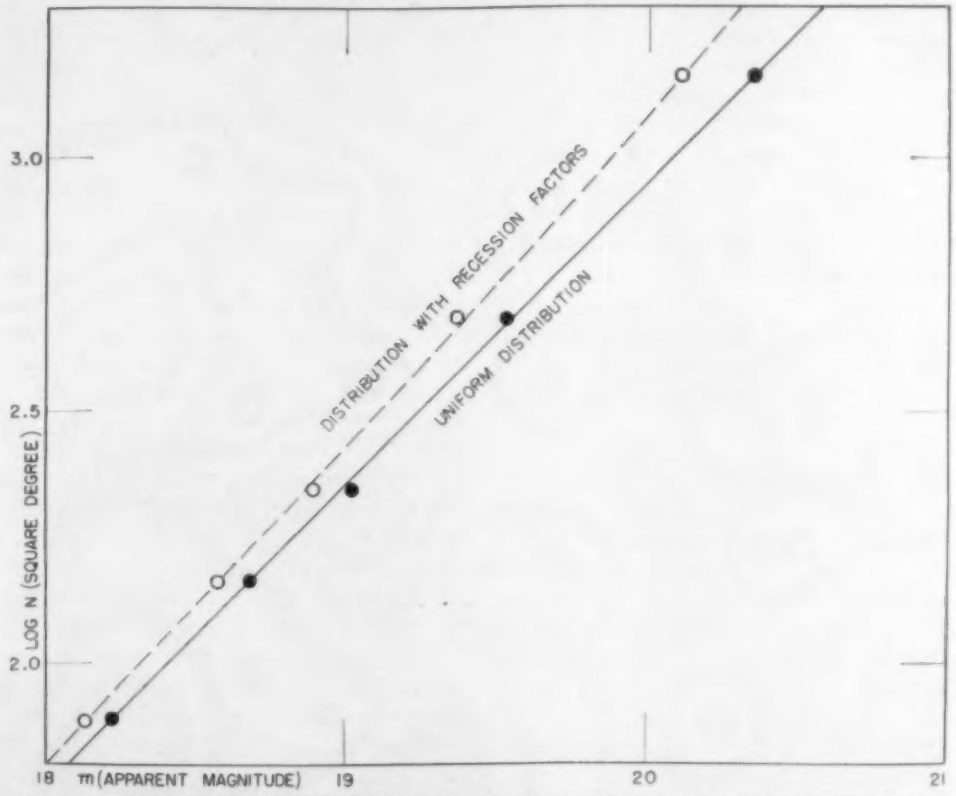


FIG. 1. DISTRIBUTION OF NEBULAE ON ALTERNATIVE INTERPRETATIONS OF RED SHIFTS

Each point represents the average number of nebulae per square degree, N, that are brighter than a particular limit of apparent faintness, m. Since m is a measure of distance, the curves represent the relation between numbers of nebulae and the volumes of space through which they are distributed. If red-shifts are not velocity-shifts (if the universe is not sensibly expanding) the numbers of nebulae increase directly with the volumes of space, and, consequently, the distribution is uniform. This result is indicated by the slope of the full line through the black discs. If red-shifts are velocity-shifts (if the universe is rapidly expanding), the additional corrections to m, demanded by the recession of the nebulae, leads to the distribution-curve represented by the broken line through the open circles. The curve implies that the density of the distribution increases systematically in all directions, leaving the observer in a favored position. Such an unwelcomed situation may be avoided by introducing sufficient spatial curvature to restore homogeneity. The required curvature implies that the universe, if it is expanding, is closed (finite but boundless) and quite small.

for two reasons. In the first place, red-shifts alter the apparent faintness of nebulae by amounts which vary with the interpretation. Since apparent faintness is the only general measure of nebular distance now available, we must know the proper corrections for red-shifts before we can construct an accurate map of the observable region. In the second place, red-shifts have been incorporated in the current theory of an expanding universe, and they furnish our only present means of testing the validity of the theory. Therefore, we must consider the phenomena of red-shifts in some detail.

The real nature of light is still uncertain; for many purposes, it may be treated in either of two ways, both of which lead to the same conclusions. We may picture light as traveling either in waves or in bullet-like parcels of energy called quanta. The waves have different wave-lengths, which are recognized by the human eye as different colors. Long waves are red and short waves are blue. Position in the ordered sequence of a spectrum is roughly indicated by color, and accurately indicated by wave-length. A red-shift implies an increase in the wave-lengths of all the light waves coming from a nebula.

On the other theory, we may speak of light quanta which carry different amounts of energy. To each wave of a particular wave-length, there corresponds a quantum with a particular energy content. The relation between waves and quanta is neatly expressed by the very fundamental relation, energy $\times$ wave-length = constant, or, in the usual shorthand notation, $E \cdot \lambda = C$. Thus the phenomena of red-shifts—the displacement of dark, absorption lines in nebular spectra—can be described either as an increase in the wave-lengths, λ, or as a decrease in the energy of the quanta, E. We may say that light-waves are lengthened in proportion to the distance of a nebula, or that light loses energy in proportion to the distance it has traveled.

Red-shifts are usually interpreted as the familiar velocity-shifts. If a luminous body is rapidly receding, the light-waves are evidently dragged out and lengthened. Consequently, all the lines in the spectrum of a receding light-source are displaced to the red of their normal positions, just as we find them in the spectra of nebulae.

Moreover, the amount of the displacement measures the velocity of recession. A shift amounting to a certain fraction of the normal wave-length represents a velocity which is that same fraction of the velocity of light. For instance, a shift of one per cent. of the normal wave-length represents a velocity of 1,860 miles per second; a shift of ten per cent., a velocity of 18,600 miles per second.

On this interpretation, the nebulae are receding from us in all directions, and their velocities are proportional to their distances. This strange phenomenon would appear to be an inherent feature of our sample; the universe itself would seem to be expanding. The velocities of recession increase at the rate of about 100 miles per second for each million light years of distance, and ultimately they reach fantastic figures. The largest red-shift actually recorded represents a speed of 25,000 miles per second. If the increase continues at the same rate beyond the limits of the spectrograph, we may estimate that the faintest nebulae that can be photographed are receding at about 50,000 miles per second—more than a quarter of the velocity of light itself.

The assumption that red-shifts are velocity-shifts is the only known interpretation that is permissible. It is true that other ways are known by which red-shifts could be produced, but in each case additional effects would be introduced which should be conspicuous and actually

FIG. 2. MESSIER 81 IS A SPIRAL NEBULA IN THE VICINITY OF OUR OWN STELLAR SYSTEM.

It is so near (distance of the order of 2.5 million light years) that some of the brightest stars can be seen in the outer arms. These stars are similar to the brightest stars in our own system, and they indicate the distance of the spiral.

are not found. We may say with confidence that red-shifts are the familiar velocity-shifts or else they represent some hitherto unrecognized principle of nature.

Nevertheless, since it is improbable that our present knowledge of the principles of nature is complete, we may examine the question from a broader point of view. Red-shifts are evidently produced either in the nebulae, where the light originates, or in the intervening space through which the light travels to the observer. If the origin is in the nebulae, then, very probably, red-shifts are velocity-shifts, and the nebulae are receding. On the other hand, if the origin is in the intervening space, the nebulae are evidently not receding—at least they are not receding at an appreciable rate. We could completely describe the law of red-shifts by stating that light loses energy in proportion to the distance it travels through space. The description seems plausible, although we do not know how the energy would be lost.

Method of Testing the Interpretation of Red-Shifts

Thus there are two possible interpretations, one of which involves motion and the other does not involve motion. Now, in principle, at least, the question of motion or no motion can be tested by direct observations. It is well known that a rapidly receding nebula would appear fainter than a stationary nebula at the same momentary distance. The recession, by thinning out the stream of quanta, would reduce their rate of arrival and, consequently, the apparent luminosity of the nebula.

The reduction factor is $(1 + v/c)$, where v and c are the velocities of the nebula and of light. At ordinary velocities, the effect is negligible, but at the enormous velocities corresponding to the observed red-shifts, it becomes appreciable. For instance, at the limits of the deepest survey, the reduction in apparent brightness would be about 23 per cent.

If we had previous knowledge of the distances of nebulae, their apparent faintness would tell us at once whether or not the nebulae were receding. Unfortunately, we can not apply the test at the present time. Our only measure of great distances is the apparent faintness itself—the very quantity we wish to use for the test. Therefore, the direct investigations end in a vicious circle.

Nevertheless, it is possible to attack the problem indirectly. We may analyze the data from the surveys on the basis of distances calculated, first, on the assumption that nebulae are not receding, and, later, on the assumption that nebulae are receding. The two sets of results may then be compared with respect to their simplicity and their internal consistency. The procedure, in effect, amounts to careful determinations of the law of red-shifts and the law of nebular distribution, using the alternative scales of distance.

The Law of Red-Shifts

Let us start with the law of red-shifts, which is known to be approximately linear. If the nebulae are not receding, we find that, within the very small uncertainties of the investigations, the law is strictly linear—light loses energy exactly in proportion to the distance. As light travels through space, each million light years of the path has the same effect on its energy. In the absence of systematic variation, we must conclude that the observable region, large as it seems to us, is too small to furnish positive information concerning the universe as a whole.

Now let us assume that the nebulae are receding, that the universe itself is expanding. The nebulae appear fainter than can be accounted for by distance alone, and consequently, the distances, as previously estimated, must be corrected

FIG. 3. VARIOUS TYPES OF NEBULAE

The four nebulae in the group, NGC 3185, 3187, 3190 and 3193, form a small sample collection of nebulae exhibiting a wide variety of types (possibly representing different stages in the evolutional sequence). The distance of the group is about seven million light years. The brightest nebula in the group is actually about 150 million times brighter than the sun, but is so remote that it appears about 270 times fainter than the faintest stars seen with the naked eye.

for the recession factor. Since the percentage corrections increase with distance, the revision is more than a mere uniform change in the scale. Therefore, the law of red-shifts, which was linear when the recession factor was omitted, can not be linear when the recession factor is introduced. The law necessarily departs from linearity. Red-shifts at a given distance are greater than those predicted by the linear law. In other words, the velocities of recession, or the rate of expansion of the universe, accelerates with distance.

This conclusion is important, for it means that we have found a general property of the observable region which changes systematically with distance. Our sample is now significant, for we can follow the trend of the change beyond the reach of our telescopes, and derive information concerning the universe at large. If the universe is expanding, we can state that it expands in a particular manner. Long ago, when the light we now observe left the distant nebulae, the rate of expansion was more rapid than it is to-day. For the last several hundred million years, at least, the rate of expansion has been slowing down.

The slowing down means that the age of the universe—the time interval since the expansion began—is less than previously supposed. The linear law pointed to an age of about 1,860 million years, and, into this relatively brief period of time, it was hoped to crowd a vast chronicle of events. Now, it is necessary to condense the history still further. How much, we can not say precisely—certainly to 1,500 million years, possibly to half that period. The significant fact is that the new data indicate a contraction of the period, rather than an expansion. Moreover, the maximum permissible time-interval of 1,500 million years is believed to be well within the life history of the earth; it is so short that we now explore with our telescopes at least a third of the entire range.

Thus the accurate formulation of the law of red-shifts presents a dilemma. The familiar interpretation of red-shifts as velocity-shifts leads to strange and dubious conclusions regarding the time-scale. The alternative interpretation that red-shifts do not measure actual motion leads to conclusions that appear simple and plausible.

The Distribution of Nebulae

The same sort of results are derived from the study of nebular distribution. Five independent surveys are now available, made with three different telescopes by two different observers. One of the surveys was made by Dr. Mayall, using the 36-inch reflector at the Lick Observatory; the other four were made at Mount Wilson, two with the 60-inch reflector and two with the 100-inch.

Each survey indicates the number of nebulae in the sky that are brighter than a certain accurately determined limit of apparent faintness—in other words, the number of nebulae within a certain specified distance from the observer. The limiting distances range from about 150 million light years for the shallowest survey to about 400 million light years for the deepest.

Thus we have available for study the numbers of nebulae in five successive volumes of space. If the distribution were uniform, the numbers of nebulae should be directly proportional to the volumes of space which they occupy. Preliminary studies had previously shown that the condition was approximately fulfilled. The more precise analysis involved the accurate determination of distances and, consequently, of volumes, on the alternative interpretations of red-shifts.

First, let us assume that red-shifts are not velocity shifts—that the universe is not expanding. Then, within the small

FIG. 4. A CLUSTER OF NEBULAE

The Corona Borealis cluster is a compact group of about 400 individual nebulae, at a distance of about 130 million light years from the earth. The photograph covers a central region in the cluster, about one tenth the area of the full moon, within which about 100 nebulae are found. The distance is so great that most of the structural details are lost. The nebulae appear as hazy patches, some elongated and some round, and the fainter ones are difficult to distinguish from stars.

uncertainties of the investigation, the numbers of nebulae are strictly proportional to the volumes of space. The distribution is uniform, the observable region is homogeneous, out to the limits of the deepest survey. There is no trace of a thinning out—no evidence of a super system of nebulae, isolated in a larger world. The observable region is an insignificant point, lost in the immensity of space. It is too small a sample to furnish positive information concerning the universe as whole.

The conclusion, you will notice, is precisely that derived from the formulation of the law of red-shifts. If the universe is not expanding, then it is vastly greater than the region that can be explored with existing telescopes. The consequence seems plausible, and even familiar.

But when we assume that red-shifts are velocity-shifts, that the universe is rapidly expanding, the picture seems to blur. Again, the recession factor alters the distances, and we may expect to find systematic departures from uniformity. However, the analysis is complicated by the fact that the light we now receive left the limits of the various surveys at widely different times in the past. While the light was traveling to us, the nebulae at the limits of the different surveys were receding, at different velocities, to still greater distances. In order to compare the surveys, it is necessary to reduce them all to a single epoch, and, as a matter of convenience, that epoch is selected as *now*, the time at which the surveys were made. Even then, the reductions are somewhat arbitrary, because they depend upon particular assumptions concerning the structure and behavior of the universe. For this reason, we must venture a little into the shadowy realm of cosmological theory.

The Theory of an Expanding Universe

The outstanding theory describes "homogeneous expanding universes which obey the relativistic laws of gravitation." It is constructed from two major propositions. The first is the underlying principle of general relativity which states that the geometry of space is determined by the contents of space. The second, the so-called cosmological principle, states that there is no favored position in the universe—that all observers, no matter where they may be located, will get the same general picture of the universe.

The cosmological principle is a sheer assumption, but it appeals to our sense of proportion. We mistrust the notion that our own stellar system has a unique position in the universe, just as our fathers eventually mistrusted the notion of a central earth. Nevertheless, the assumption, although plausible, leads to some remarkable conclusions. For instance, if we see the nebulae receding in all directions from our position in space, then every other observer, no matter where he may be located, will see the nebulae receding in all directions from his position.

The kinds of universes which are consistent with the two propositions are demonstrated by intricate mathematical reasoning. Such universes are homogeneous, and they are unstable. In their normal states they are either contracting or expanding. The distribution of matter is uniform at any instant, but the average density changes systematically with time. Theory, in its present form, does not indicate the direction of change or the rate of change; our universe might be contracting or expanding, and at a rate that is rapid or imperceptible. However, the theoretical investigators, for the most part, seize upon the observed red-shifts, interpret them as velocity-shifts, and present them as visible evidence that the actual universe is now expanding rapidly.

The geometry of such a universe is not the familiar geometry of Euclid. It is

another, more general, kind known as the geometry of Riemann, which involves the highly abstract conception of spatial curvature. The concept can not be visualized and it will not be discussed in detail. Two features, however, must be mentioned. In the first place, spatial curvature may be positive or negative. If positive, the universe is closed and finite (like the surface of a sphere); if negative, the universe is open and infinite. In the second place, the amount of curvature is measured by the radius of curvature. A small radius means highly curved space, while a large radius means small curvature. Flat, or Euclidean, space is the limiting case of zero curvature, and may be described by the statement that the radius of curvature is infinite.

The various features—homogeneity, instability and spatial curvature—are necessary characteristics of the universe, provided we accept the relativity principle and the cosmological principle as initial assumptions. A universe is then fully described when we know the nature of the expansion or contraction, the nature of the curvature, and a third quantity, called the cosmological constant, which is associated with the contents of the universe.

The three characteristics might conceivably lie anywhere within wide ranges of values. Therefore, the theory presents a long array of possible worlds. The problem for the observer, it seems, is to determine the three characteristics, and thereby identify among the possible worlds the actual universe which we inhabit. The law of red-shifts, when we interpret them as velocity-shifts, establishes the nature of the expansion, and, to this extent, has already restricted the array of possible worlds. The law of nebular distribution, as will appear, supplies the two remaining quantities.

The Distribution of Nebulae and Spatial Curvature

Now we may return to the surveys. Let us assume that red-shifts are velocity-shifts and that we do inhabit a homogeneous, expanding universe which obeys the relativistic laws of gravitation. We correct the apparent luminosities for the recession factor, reduce the surveys to a single epoch, and then examine the distribution of nebulae. We find that the distribution is not uniform—the density increases outward, systematically in all directions. The observable region appears to be non-homogeneous, and we seem to occupy a special, favored position in the universe.

This situation, as has been mentioned, is as unwelcome as the earlier notion of a central earth. Moreover, it presents a discrepancy because the theoretical universe is homogeneous. For these reasons, we are forced to assume that the departures from uniformity are not real, and we search for some neglected factor which may compensate the apparent departures.

Now, in the whole of the theory, there is just one possible way of making the necessary compensation, namely, by means of spatial curvature. First we postulate rapid expansion, and it leads to discrepancies; then we postulate an additional effect in order to balance the discrepancies introduced by the first. The procedure seems artificial, but it offers the only possibility of preserving intact the theory of a homogeneous expanding universe. The curvature required to restore homogeneity is positive and very large. In other words, the radius of spatial curvature is positive and small—about 470 million light years, or slightly less than the penetrating power of the 100-inch reflector.

This result indicates that the universe, if it is expanding, is closed and finite. It has no boundaries in solid space, but the volume is finite, and, at the present

time, is very small. With the 100-inch reflector, we now explore about a quarter of the entire universe. The conclusion seems strange and dubious, but it appears to be a necessary consequence of the theory of a homogeneous expanding universe.

It might be mentioned, in parenthesis, that the radius of spatial curvature is a quantity that lies in a fourth or higher dimension. The unbounded universe of the theory has no radius in solid, three-dimensional space. The dim analogy, in two dimensions, is with the surface of a sphere, not with its volume. The radius of curvature of such a surface is, of course, the radius of the three-dimensional globe, but our analogy is restricted to the surface only. To an observer on the surface, all investigations would be restricted to the surface. He might imagine a circle, centered upon himself, whose radius corresponded with his radius of curvature as stretched over the surface of the sphere. This circle would enclose only a certain fraction of the total surface. Moreover, the line of sight, starting from the observer and proceeding along the surface, would never reach an end. The surface is closed and finite, but it is unbounded.

So, in the universe of theory, the line of sight, starting from the observer and advancing through solid space, never reaches a boundary. So likewise, the volume within a sphere whose radius is the radius of spatial curvature stretched through three-dimensional space, is but a certain fraction of the volume of the universe, namely, about one fourth.

The nature of the spatial curvature is the second of the three significant characteristics to be suggested by the observations. The third, and last, namely, the cosmological constant, can not be evaluated precisely, but upper and lower limits are readily calculated. The constant is associated with the contents of the universe and, while we know the nebulae fairly well, we do not know what lies between the nebulae. Thus the contents of the universe are not completely known. However, the constant is not wholly independent of the curvature, and this fact, together with the evident proposition that internebular space can not be less than empty, furnishes curiously narrow limits between which the constant must lie. It is definitely a positive quantity and it is rather small—the numerical value is of the order of 5×10^{-18} (years)$^{-2}$.

Possible Worlds

We may now identify the type of universe which we are supposed to inhabit, among the array of possible types that are offered by the theory. It is an "ever-expanding universe of the first kind"—in other words, a universe of the type associated with the name of Lemaitre and, later, of Eddington and others. It is a finite universe, quite young and small. Less than 1,500 million years ago, it started to expand from a relatively small, compact mass. At first, the expansion was rapid, but as time passed, the rate has steadily slowed down. To-day, we explore with our telescopes about a quarter of the entire volume and about a third or more of the past history. The expansion will continue, and the universe will approach nearer and nearer to the de Sitter configuration—a universe so vast, so thinly populated, that each nebulae is completely isolated and lonely in the immensity of space.

The remarkable features of this universe are all introduced by the initial assumption that red-shifts are velocity-shifts which measure expansion. Otherwise, our sample is insignificant, a small homogeneous region of a universe which extends indefinitely beyond the range of our greatest telescope. The latter conception would probably be adopted as a matter of course were it not for the fact

that, in such a universe, we do not now understand how red-shifts could be produced.

But if red-shifts are the familiar velocity-shifts, if the nebulae are receding, the scale of distance must be revised and distorted by the recession factor. The distortions necessarily imply that the previously uniform characteristics of the observable region must vary systematically with distance. Our sample then becomes significant and indicates the nature of the universe as a whole.

However, the systematic variations are exact equivalents of the recession factor. The departures from a linear law of red-shifts, the departures from uniform distribution, the spatial curvature required to restore uniformity, are each one the recession factor in another form. The "ever-expanding universe of the first kind" follows directly from the interpretation of red-shifts as velocity-shifts—and, at the moment, we know of no other permissible interpretation.

Thus the study of our sample of the universe, with the greatest telescope available, presents a dilemma. One set of phenomena, namely, red-shifts, is not yet fully explained on the basis of direct observations. The familiar interpretation leads to a strange and dubious universe; the alternative possibility, which some might call a strange and dubious interpretation, leads to a simple and familiar conception of a universe so vast that it can not be described in its totality.

It is possible that theory may be revised to evade the difficulty. Otherwise the definitive solution of the problem will doubtless await the construction of still larger telescopes. Meanwhile it may be emphasized that the field has been opened, the problem has been formulated, and the possible solution reduced to a narrow range, largely by the contributions of one instrument, namely, the 100-inch reflector. The revelations of this telescope seem to force upon us a choice between a small, finite universe and a universe indefinitely large plus a new principle of nature.

THE PANAMA CANAL: SOME GEOGRAPHIC INFLUENCES

By Dr. W. O. BLANCHARD

PROFESSOR OF GEOGRAPHY, UNIVERSITY OF ILLINOIS

In 1914, 400 years after Balboa crossed the Isthmus of Darien, the Panama Canal was opened to the world's shipping. For many years preceding its completion, extensive studies were made to determine what countries and routes would be affected, the volume and character of the probable traffic and the tolls which the Canal might be expected to yield. 1934 marked the completion of twenty years of operation of the waterway. It would seem an appropriate time to examine the record of its accomplishment and its promise of future performance.

At the outset we must recognize the fact that the entire period of operation has been an abnormal one in world industry and trade. Furthermore, the conditions prevailing have operated, in the main, to curtail the use of the waterway. The world war, the slides in the Canal, the post-war boom and the world-wide depression which followed, have all operated to disorganize shipping, and these influences have been naturally reflected in the Canal business. With these facts in mind, let us examine the twenty-year record of its contribution to the maritime world.

Volume of Traffic

In spite of the abnormal circumstances cited above, the waterway has made an impressive record in its service to ocean shipping. Thus, there have been passed, in the two decades of operation, approximately 77,500 commercial vessels carrying some 364,000,000 tons of cargo.

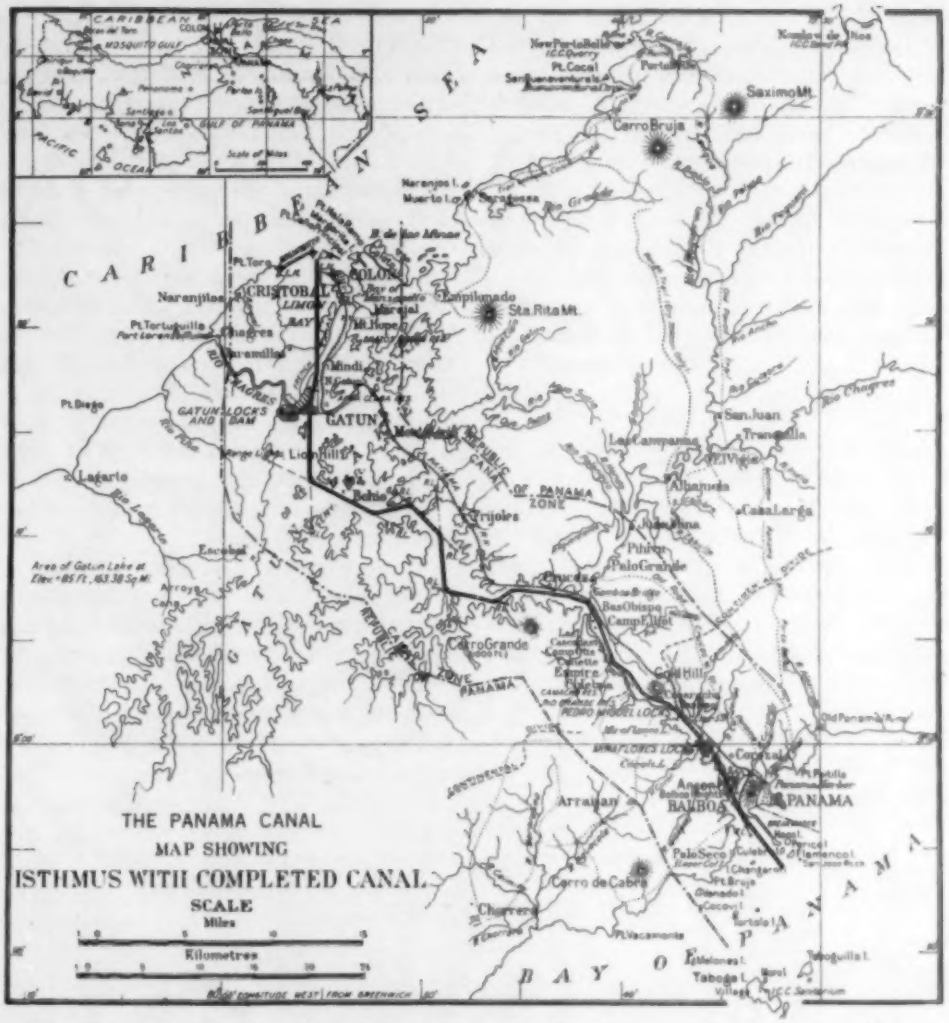
In addition to the *commercial* vessels, the waterway has been extensively used by vessels belonging to the governments of the United States, Colombia and Panama, as well as ships transited solely for repairs. In 1934, for example, over 500 of such toll-free passages were made. Most of these were by boats belonging to the American naval and military forces.

What the Canal would have accomplished had not the world war and other economic disturbances intervened can not, of course, be answered. However, it is certain that it would have been much more active than it has been. With all its fluctuations, the waterway has, with the exception of brief periods, increased its usefulness. During the second decade the number of transits was more than double those of the first ten years.

In Fig. 1, showing the cargo movement through the Canal, three distinct periods may be discerned. The first, covering the initial fifteen years, shows an almost uninterrupted annual increase in traffic. During the first half of the period the rate of growth was slow, but after some eight years, the California oil boom came on, followed by improving world trade and industrial conditions, so that the Canal business increased rapidly, reaching about 31,500,000 tons in 1929. The second period, 1929 to 1932, records a precipitous decline, a reflection of the world-wide depression. The third period, 1932 to 1934, represents a recovery of almost one half of the amount lost in the second period.

Commodities Moved

Because of the marked difference in the stage of economic development in the Atlantic and Pacific regions, there has always been a marked difference in both the character and amount of commodities



moving in opposite directions through the Canal. These differences are brought out in Fig. 2. In general, the Pacific countries contribute bulky products—lumber, wheat, petroleum, preserved fruits and fish from North America; nitrates and iron ores from South America; and wool from Australia. Silk and tea from the Orient constitute an exception to the general rule, since they are very compact and of relatively high value.

Commodities from the Atlantic borders, on the other hand, are, in general, manufactured or semi-manufactured goods of small bulk and large value. Iron and steel wares have long been the leading item.

As a result of this difference in the character of the goods, there has been an unfortunate lack of balance in cargo movement. For the whole period during which the Canal has functioned, the ratio of the tonnage of the Pacific to that of the Atlantic has been about 2 to 1 (see Fig. 3). The disparity seems to be growing greater. In 1934, it was about 3 to 1. For certain routes it was much

worse. Thus European manufactures moving to Pacific America have filled only one seventh of the return cargo space. This puts a heavy burden upon shipments from these regions to Europe, and conversely, makes for low freight rates on west-bound vessels. As a result, Europe has become a keen competitor of the eastern United States in supplying manufactures to Pacific America. Even such bulky cheap commodities as cement and sand have been carried from Europe to the western United States.

Classes of Vessels

According to the nationality of the vessels transiting the Canal, either British or American ships have led in every year thus far. From 1915 to 1918 British ships led; in the next sixteen years American vessels occupied first place. In 1935 the ratio of American transits to British was almost 2 to 1. The ratio based on cargo tonnage was about the same.

The preponderance of American vessels is to be expected in view of the relative importance of our cargo movement. This is especially true of the important intercoastal trade, which is limited by law to American vessels. Great Britain's high rank is due to her preeminent position in ocean shipping as well as to her interest in New Zealand, Australia and Canada.

What is the character of the average ocean-going commercial vessel transiting the Canal? The average of such ships, above 300 net tons, for the years 1933–35 inclusive, was a boat of approximately 5,500 net tons. It paid tolls of about $4,600 and carried 4,700 tons of cargo. If only laden boats were counted the average cargo tonnage would have been 5,600 tons.

With respect to motive power the Canal records show a constantly increasing proportion of oil burners as compared with the number using coal. For the fiscal year 1935, of the ocean-going commercial vessels recorded, about two thirds were steamers and about one third

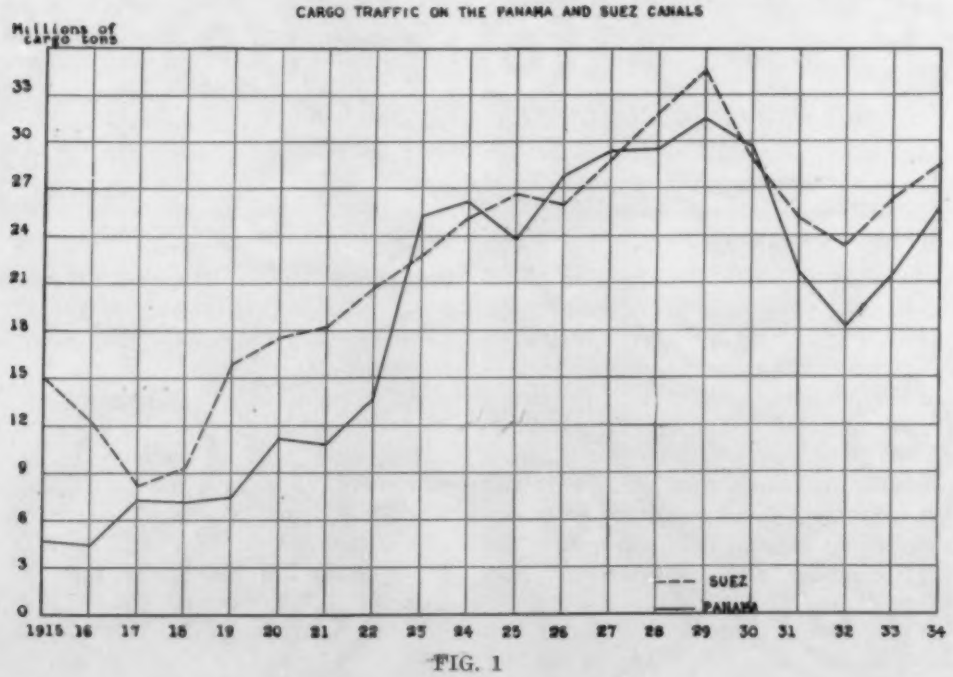


FIG. 1

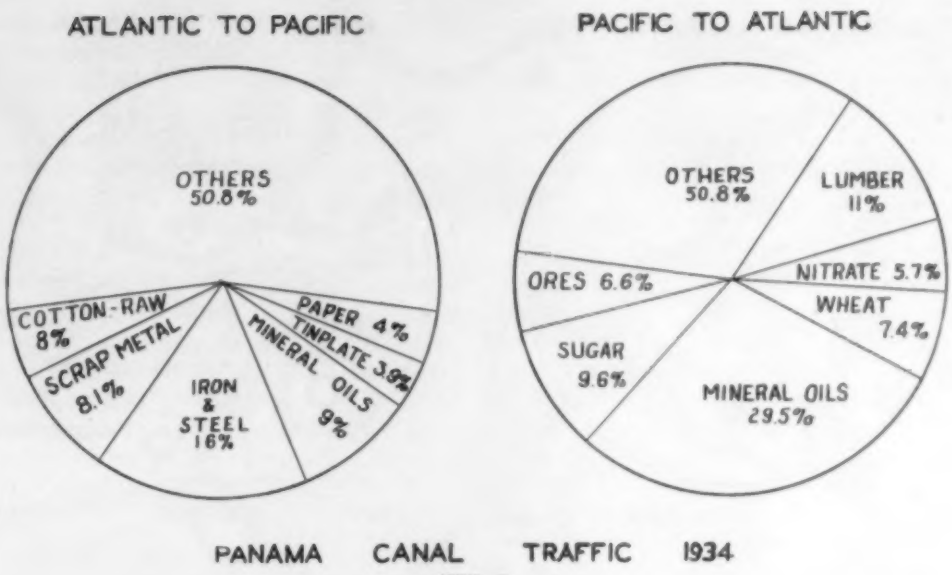


FIG. 2

were motor ships. Of the steamers, about three fourths burned oil and the remaining one fourth, coal. The abundance of oil and scarcity of coal in the Canal region and in the Pacific borderlands explains in part this trend toward oil as a motive power.

Aside from the general cargo vessels using the Canal, tankers have played an important rôle. These specialized carriers became important in 1923 when 913 transits of such boats were recorded. The peak movement occurred the next year with 1,704 passages. The number has gradually declined to 791 in 1935. Even in this latter year, however, oil made up almost one fifth of the total cargo passed.

Routes of Greatest Importance

If we analyze the records of shipping through the Canal for the twenty years of its operation, it will be found that the great bulk of the traffic is concentrated into a very few definite routes. From what has been said above, it might be expected that those routes along which goods were being sent to or from the United States would be most important. And so they are. As shown in Fig. 4, of the movement through the Canal from Atlantic to Pacific, the United States intercoastal route accounts for 33½ per cent.; that from the United States to the Far East, about 21.3 per cent. Thus, these two make up over one half of the total in this direction.

FIG. 3

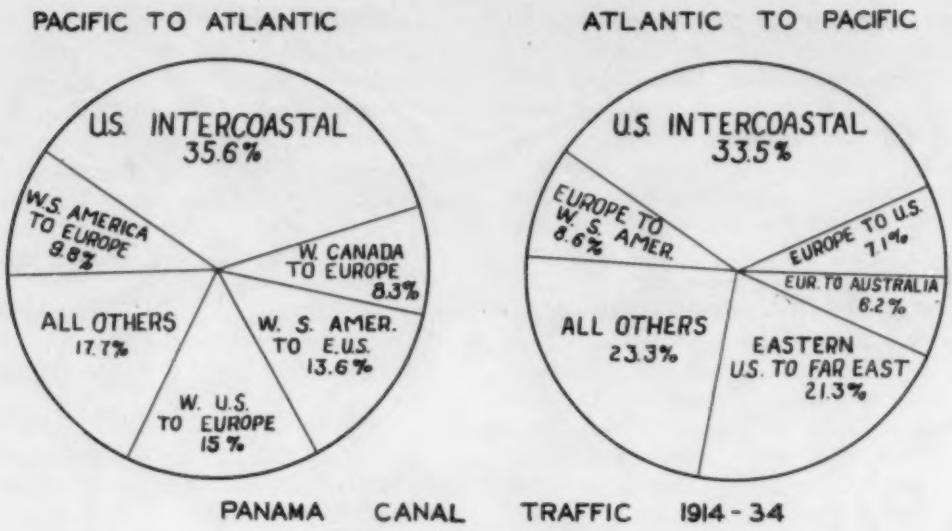

PACIFIC TO ATLANTIC
U.S. INTERCOASTAL 35.6%
W.S. AMERICA TO EUROPE 9.8%
W. CANADA TO EUROPE 8.3%
ALL OTHERS 17.7%
W. S. AMER. TO E.U.S. 13.6%
W. U.S. TO EUROPE 15%
ATLANTIC TO PACIFIC
U.S. INTERCOASTAL 33.5%
EUROPE TO W. S. AMER. 8.6%
EUROPE TO U.S. 7.1%
EUR. TO AUSTRALIA 6.2%
ALL OTHERS 23.3%
EASTERN U.S. TO FAR EAST 21.3%
PANAMA CANAL TRAFFIC 1914-34

FIG. 4

Of the traffic transiting the waterway in the opposite direction, Fig. 4 shows the United States again to be far in the lead with 35.6 per cent.; the United States with Europe, 15 per cent.; and South America to Europe, 13.6 per cent. These three play the major rôle and together account for about two thirds of the total in this direction.

Regions Influenced by the Canal

Whence come all these cargoes? To what shores are they bound? Since the Canal joins the Atlantic and Pacific, its service should naturally be to the lands bordering these oceans. This is in general true, but, as shown in Fig. 4, there are notable exceptions. Thus the Atlantic coasts of both South America and Africa have their complementary trade areas in the North Atlantic; consequently the Canal is of little importance to them. The interests of the Far East and Australia likewise will be limited, for their trade with Europe will go mostly via Suez or Cape of Good Hope.

Among individual countries affected by the Canal, the United States occupies a unique position. American *domestic* commerce at present accounts for over one third of the total Canal business. American *foreign* commerce can be charged with another 40 per cent. This leaves only about one fourth of the Canal traffic moving between countries or parts of the same country other than the United States.

Next in importance among regions using the Canal is Europe, especially in its trade with the Pacific coast of both the Americas. It will be noted in Fig. 4 that of all the east-bound Canal traffic, that from the western United States to Europe ranks next to our intercoastal movement, although it is, to be sure, a poor second. As indicated elsewhere, these two routes from Europe to the two Americas suffer severely from the lack of balance on the two legs of the journey.

While the Canal brought the two coasts of the United States nearer, it may be noted that in so doing it placed the Mississippi Valley at a decided relative disadvantage. Industries, for example, in the Chicago district, which formerly supplied a market on the Pacific coast, now find themselves handicapped in

competition with plants located on the Atlantic seaboard.[1]

The change has not been entirely to the advantage of the Pacific coast. Those ports have lost some of the transshipment business between the eastern United States and the Far East that used to go by rail to these Pacific ports, but now goes direct by the all-water route.

Other changes have occurred and still others will be found advantageous as normal conditions return and the readjustment is completed. It is interesting to note in this connection that raw silk, which formerly moved from the Far East to Seattle or San Francisco, there to be transshipped by rail to our eastern seaboard, is now practically all going via Panama.

[1] Since 1914 (the year of the opening of the Panama Canal) it is said that to move a ton of staples via the cheapest route, New York, which was then 1,904 cents from San Francisco, is now 1,280 cents away. Chicago, which was then 2,610 cents from San Francisco, is now 2,946 cents away. Chicago has moved away by 336 cents. New York has moved nearer by 224 cents. Furthermore, Chicago has moved 494 cents away from the Atlantic seaboard and from South America.

Influence upon Transcontinental Railways

The effect of the opening of the new water route on the United States railroads was far-reaching. In 1911, these railroads were estimated to have carried between five and six million tons between the borders of the Atlantic and Pacific. That portion going via Magellan or the Panama or Tehuantepec railways was less than a million tons. By way of contrast, in the Canal's best year (1929) it moved in our intercoastal trade about twice the combined rail and water movement of 1911.

Essentially all the water and probably

Photo by U. S. Army Air Serv.

PANAMA CITY, WHILE WITHIN THE CANAL ZONE, IS UNDER THE JURISDICTION OF THE REPUBLIC OF PANAMA.

one half of the rail intercoastal movement of 1911 was diverted to the new waterway. This was a staggering loss for the railroads—a blow from which they have not yet fully recovered.

About one half of the Canal's intercoastal business is new, developed because the low rates attracted tonnage that never would have moved without this new attraction. This economical transportation was, of course, available only to the immediate hinterlands of the two coasts—say within two or three hundred miles of tidewater.

The savings on our intercoastal traffic have been estimated to average about $10 per ton. In addition, overland rail rates have been forced down by the potential alternative route, thus resulting in additional savings to the shippers still using the railroads. It seems possible that the total cost of the Canal could be justified on the basis of the savings on our coast-to-coast traffic alone.

The Canal as a Military Asset

One of the major objects in constructing the Canal was to facilitate the movement of our military and naval forces between our coasts. It will be recalled that the voyage of the battleship *Oregon* around South America to join the Atlantic fleet during the Spanish-American war was a powerful factor in arousing American public opinion to the necessity of removing the Isthmus barrier.

In recognition of its military value, the Panama Canal Zone was made a military reservation. The Washington office of the Canal Zone is under the Secretary of War, and the governor reports to that cabinet official. Most of the gov-

U. S. AEROPLANE CARRIER "SARATOGA" IN PEDRO MIGUEL LOCK.
THE LOCKS WERE BUILT BEFORE SUCH BOATS WERE USED AND THIS ONE IS BARELY ABLE TO SQUEEZE THROUGH.

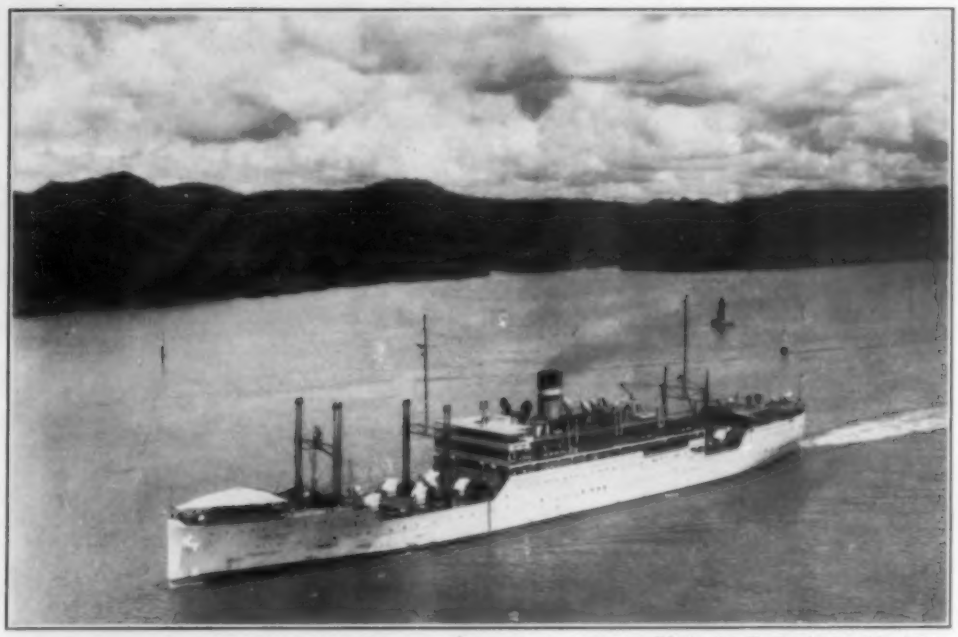


Photo by U. S. Army Air Serv.

U. S. ARMY TRANSPORT ST. MIHIEL CROSSING GATUN LAKE.
NOTE THE FORESTED HILLS CHARACTERISTIC OF THE CANAL ZONE.

ernors have been chosen from the Army, and the Canal fortifications have been regarded as a part of our coast defenses. Army posts have been established there and a military population of some 8,000 men is quartered there. Both Canal entrances are fortified and there have been constructed flying fields, air service hangars and wireless stations.

The Canal was opened within a few months of the outbreak of the world war. Although it was not found necessary to move the fleet through the waterway during the war, the Canal was an important factor in the successful prosecution of the cause of the Allies. Huge quantities of supplies from the Pacific were sent through. Included in these cargoes were some three and a half million tons of Chilean nitrate for explosives. Allied vessels, both merchant and naval, found at the Canal terminals supplies of foodstuffs and fuel as well as repair facilities, hospitals and other services. Since the war, our fleet has on several occasions passed through the Canal without serious delay or mishap, showing conclusively its value as a military asset.

Future of the Canal

The present capacity of the Canal is estimated, on the basis of 7,500 net tons per lockage, at from 70,000,000 to 75,000,000 Panama Canal net tons annually. This is about three times the 1934 tonnage actually using the Canal. When necessity arises, it will be entirely feasible to expand the capacity by constructing a third flight of locks. This would enable the waterway to handle about five times the present traffic. Likewise it can always be turned into a sea level canal if it seems desirable. In general, it may be said that the facilities are now ample, and they can be expanded to care for any increase likely to develop within the next century.[2]

[2] According to the engineers in charge it would even be feasible to fill the locks by pumping from the sea as a last resort.

Photo by U. S. Army Air Serv.

A NATIVE VILLAGE TYPICAL OF THOSE OF THE REPUBLIC OF PANAMA.

The Canal a Notable National Accomplishment

As an engineering accomplishment the Canal ranks among the foremost undertakings of man. In sanitation it represents one of the greatest triumphs of man over disease, with a health record comparable with that of many American cities. In its operation it has profoundly affected world shipping and quickened the commercial life of vast areas. It is a piece of work of which every American can be justly proud.

The story of a great torrential river made over into a navigable waterway, of a great mountain ridge grooved and bridged by a great artificial lake, of a pest hole transformed into a healthful dwelling place, of all this being accomplished without the least suspicion of graft or corruption—such an accomplishment is one of which any nation may well be proud. It may never pay in tolls the actual expenditure, but directly and indirectly it has been a highly profitable investment. In addition, it has been an impressive lesson for our Latin American neighbors—an example of what may be accomplished for peaceful intercourse among the nations.

FISHES AND RINGS

NOTES AND ILLUSTRATIONS OF VARIOUS FISHES WEARING RUBBER BANDS

By Dr. E. W. GUDGER

ASSOCIATE CURATOR OF FISHES, AMERICAN MUSEUM OF NATURAL HISTORY

To some of my readers my title will at once recall the stories of beauteous maidens, who, toying with their rings, dropped these from bridges or boats into the streams below. Then followed weepings and wailings (and probably gnashings of teeth), which continued until some obliging fish, when caught nearby, would be found to have in mouth or "inwardness" the missing ring. Restoration of this to the bereft maiden was always followed by smiles, happiness and serenity.

Then there is the oft-repeated tale in the monastic legends of the Dark and Middle Ages of the wedded wife who loses her wedding ring, of the husband who notices its absence and becomes insanely jealous, and of the obliging fish which, with or without the intervention of some saint, retrieves the ring and heals the breach. Perhaps the recital of one of these stories may not be amiss. Thus it is reported of St. Kentigern that:

> A lady of good place in the country having lost her ring as she crossed the river Clyde, and her husband waxing jealous, as if she had bestowed the same on one of her lovers, she did bemean herself unto Kentigern, entreating his help for the safety of her honour; and that he, going to the river after he had used his devotion, willed one who was making [ready] to fish to bring the first [fish] that he caught, which was done. In the mouth of this fish he found the ring, and sending it to the lady, she was thereby freed of her husband's suspicion.

Thus both the fish and the saint did their good deed for the day and everything was lovely. Furthermore, as proof of the authenticity of this account, it is stated that "the see and the city of Glasgow [the scene of the Saint's labors, 514–601 A.D.] do both of them bear in their arms a fish with a ring in its mouth even unto this day."

It would be interesting to go further with these accounts, but they make "another story" which I hope possibly to write some other day. This article will deal with fishes *wearing* rings, and rings of but one kind—rubber. Other fishes wearing rings of other kinds will be dealt with later, *d. v.*

I. Bony Fishes Wearing Rubber Bands

It is an interesting fact that in various parts of the world various ordinary bony fishes have been captured wearing rubber bands. My own collection of such is large and valuable. These will first be described, and next citations from the literature will be given. It seems worth while to bring all these interesting data together and thus effectually to establish the truth of this often doubted phenomenon.

A Mackerel with a Rubber Band

Here is how it all came about so far as I am concerned. On August 1, 1927, a telephone message from the director said, "Would you mind coming up to my office?"; and I answered "I'm on my way." Wondering what I had or had not done, I walked into the office to be handed a small mackerel (*Scomber scombrus*) with a rubber band around it. "What do you think of it?" he queried. "Interesting specimen," I replied. Then he gave me the brief history of the fish

and said, "I wish that you would see what you can make of it," and I retired.

The fish having been caught the previous day off Clinton, Connecticut, was in pretty "high" condition, so I brought it to my office and put it in alcohol in my tank of piscine curiosities, washed my hands and—being hard pressed with other work—promptly forgot it. About two weeks later, I saw the director, who asked about the fish. I answered that it was in alcohol to be rid of the bacteria and bad smell and to be hardened for handling. I next went on vacation and, after my return in late September, when I saw the director, he again asked about his fish. I spoke of my vacation and of other work crowding in, but he said with mock severity—"If you do not write up that fish, I'll have to give you a permanent vacation."—I described it.

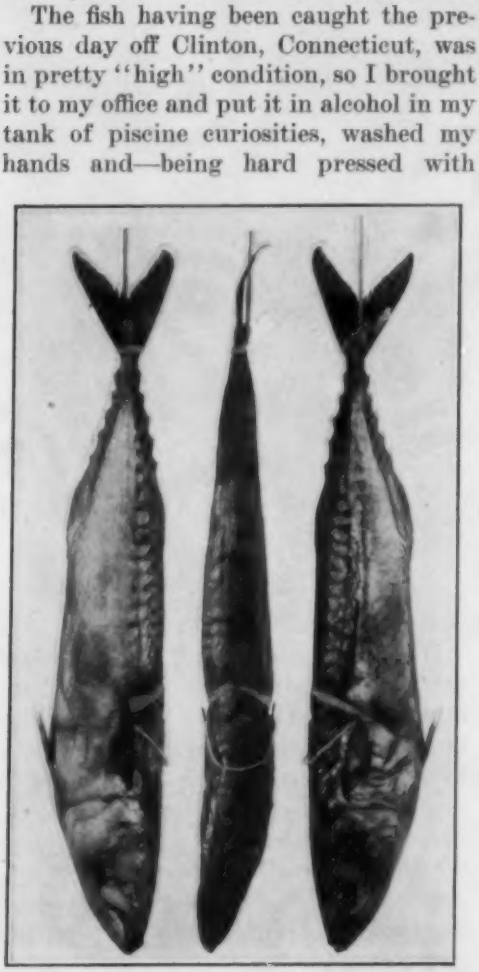


FIG. 1. A DORSAL AND TWO LATERAL VIEWS OF A MACKEREL WITH A RUBBER BAND.

THE TWO LATERAL VIEWS SHOW THAT THE FLAT BAND HAS CUT ITS WAY THROUGH THE ABDOMEN HALF THE DISTANCE TO THE UPPER SURFACE. THE TISSUES HAVE REGENERATED, CLOSING UP THE WOUND. THE CENTRAL FIGURE SHOWS THE TWO GROOVES CUT BY THE BAND ON THE BACK OF THE FISH.

As the photograph (Fig. 1) shows, when the fish came to me the flat band had cut into the body from the belly side and the cut had healed up so that the band was rove clear through the body just below the level of the intestine. Across the back it had cut two grooves: an anterior deep one, which was plainly the older, and a posterior and shallower one in an oblique position. The anterior one had formed scar-tissue in it, but the second (formed by the band as it grew softer and slacker) was still unhealed, as the figures show. Most interesting of all, however, is the faint scar on either side of the fish showing where the cut has healed up as the band moved higher and higher from the soft ventral surface. Here we have strong evidence of the great regenerative powers of the tissues in a fish—a cold-blooded vertebrate.

More Mackerels with Rubber Bands

The description and three figures of this fish were published in April, 1928. The story aroused much interest and was given wide newspaper publicity, and for some time numerous like isolated items about rubber-banded mackerel appeared in the daily press.

All this brought in to me a great deal of corroboratory data, particularly from Boston, the center of the mackerel fishing industry in our waters. Mr. F. F. Dimick, the efficient secretary of the Boston Fish Bureau, sent me his Report for 1894 in which he had recorded at least 5 specimens of rubber-banded mackerel. Again in his Report for 1925,

he noted that many such mackerel had come under his eye during the 20 years past.

Then Mr. R. A. Nesbit, of the U. S. Bureau of Fisheries, wrote me that, in making statistical studies of mackerel at the Boston Fish Pier, he had handled thousands of mackerel and had found the rubber-banded ones to be "surprisingly common."

This plethora of data was incorporated in another article on fishes with rubber bands. Publication of this in England led to the incoming of more data and specimens. Most of these, however, came from Boston, where Mr. Nesbit had been succeeded at the Fish Pier by Mr. F. E. Firth, who as early as 1930 began to send me data and *specimens* of mackerel with rubber bands about their bodies. In fact, he has sent in so many specimens that I have had to beg him to desist for lack of space in my tank to hold them.

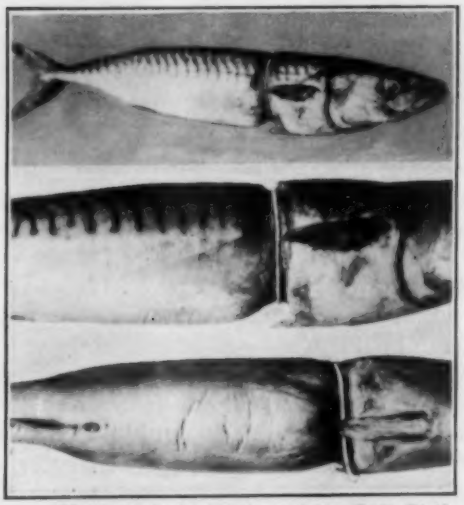
There are in this tank of piscine curiosities 10 undescribed mackerel with rubber bands. Nine of these were sent to me by Mr. Firth. These vary in total length from 13.5 inches to 18.25 inches. Five of them have the rubber bands or their marks around the "neck" of the fish—*i.e.*, across the back of the head, underneath the gill-covers on the sides, and across the "isthmus" or narrow part of the fish's throat where the two gill-covers come together, leaving an uncovered V. On the dorsum, in every case the rubber band has cut a furrow deeper than its own diameter and about three times as wide. In the isthmian region, in two cases there is no cutting, in the other three cutting has begun but has not proceeded far.

Sometimes in this region, the constriction of the band is so great as to nearly cut the head off. Such is specimen No. 10, a headless fish, sent to the museum by the Teddy Sea Food Company, of Fulton Market. It was caught near Block Island in June, 1934. I judge that the head was on this fish when it was rounded up in the net, but that it was broken off in handling the fish—"bailing" them out of the net and into the hold of the fishing vessel. This fish has had another band around the body about over the middle of the dorsal fin. This has left a distinct mark around the body, but has only barely cut through scales and the epidermis.

We now turn to the other mackerels sent in by Mr. Firth. Two have the band rove through the body something like what is seen in Fig. 1. In both cases there is a distinct scar, showing where the band has cut into the tissues of the belly wall. These have regenerated and thus the cut has healed. In the second and slightly better preserved fish the band has reached the level of the alimentary canal and has lifted this up, making an abrupt bend in it. The first one has two furrows on the back like that to be seen on the fish shown in Fig. 1, and the second has a much deeper single cut. The third fish has had the ventral cut to heal up, leaving the band embedded, but on the dorsal surface the cut is over one fourth of an inch wide and in depth goes well down toward the backbone. This fish is in transition toward the next group.

Each of the two remaining fish has the body encircled by the band about over the middle of the dorsal fin. On the back each has a broad furrow cut down almost to the level of the backbone. On the ventral side each fish has been cut beyond repair nearly up to the level of the under side of the backbone. In this condition these fish grade right up to the headless specimen. But for the toughness of muscles and ligaments tying together the segments of the spinal column, these fishes would easily have been torn in two. Unfortunately they were poorly preserved here, and the viscera have so far gone to pieces that no study can be made of the effect of the band on these.

Of all the photographs on hand, only three will be reproduced (Fig. 2). The first shows in lateral view a whole mackerel which has around it just in front of the dorsal fin a round rubber band, which has made a deep groove. The second gives a "close up" of this lateral view, and the third shows the groove across the belly of the fish. This groove is a wide one, evidently caused by the round band which has had sufficient resiliency to make a groove and yet has had sufficient play to make and keep the groove so



—Photographs by courtesy of Mr. F. E. Firth.

FIG. 2. THREE VIEWS, TWO LATERAL AND ONE VENTRAL, OF A MACKEREL WITH A ROUND RUBBER BAND.

THIS ROUND BAND HAS MADE A DEEP U-SHAPED GROOVE ALL AROUND THE BODY OF THE FISH. THIS IS IN MARKED CONTRAST TO THE CUT MADE BY THE SMALLER FLAT BAND SEEN IN FIG. 1.

wide that no healing has and possibly none can take place. Despite all, the fish seems reasonably fat and well fed.

One wonders how these mackerel could have undergone such injuries without dying. But these cold-blooded animals seem to respond slowly to injury, especially if this comes slowly, and they have enormous recuperative and reconstructional powers. All of which facts are plainly attested by this series of mackerels afflicted with rubber bands.

These specimens are, however, but a fraction of the number of rubber-banded mackerel which have come under Mr. Firth's keen eye each mackerel-fishing season since he became interested. His letters are full of such records. For instance, late in August, 1930, he wrote that out of one "trip" of mackerel of only 1,500 pounds from Cape Cod, he had gotten 12 banded mackerel. These fish were small (about 13 inches long) and were probably about two years old. These bands were around the bodies just behind the heads and at least one was rove through the fish—*i.e.*, the band had cut into the body and the flesh had healed up.

RUBBER-BANDED BLUEFISH

The mackerel is a pelagic fish found in great schools at the surface of the sea miles away from land. The bluefish (*Pomatomus saltatrix*) is a member of a family of fishes not very distantly related to the mackerels. It too is a pelagic fish found off shore on the ocean's surface, and having much the same habits of life. With these facts before him, the reader may not be surprised to learn that it too is found with rubber band adornments.

My earliest account is from Mr. Nesbit, who writes that he had seen such a specimen in 1928. In 1933 Dr. J. S. Gutsell was in charge of the station of the U. S. Bureau of Fisheries, at Beaufort, N. C. On January 4 of that year, he took a 10-inch bluefish "wearing a rubber band around the body just in front of the pectorals." This had cut into the fish a considerable extent both above and below. Later, Mr. Leonard Ross, of Washington, N. C., wrote me of a three-quarter-pound bluefish with a rubber band which had been brought in to the Washington Field Museum. His description reads as follows.

—*After Mr. G. P. Whitley, 1935.*

FIG. 3. AN AUSTRALIAN GARFISH WITH A RUBBER RING.

THIS IS THE ONLY FISH WITH A RUBBER BAND THUS FAR REPORTED FROM THE SOUTHERN HEMISPHERE.

This fish had a rubber band around its neck or body just behind its head. The band being much too tight had embedded itself into the flesh of the fish on the underside. The skin and scales have healed over. The scar was hardly noticeable, and the band could be slipped around backward or forward by merely pulling it through the hole. The fish was alive when caught and did not seem to suffer from its plight.

Here again we have evidence from an eye-witness that this fish was not seriously incommoded by a rubber band rove through its body.

A Garfish with a Rubber Band

The garfishes all have long snouts and long slender bodies and are thus well fitted by nature for the acquiring of rubber bands in a fashion to be explained later.

Thus in August, 1934, in the far distant harbor of Sydney, Australia, a ten-inch ocean garfish with an encircling round rubber band was captured and was brought to the museum in Sydney. There it was recognized as the common Australian gar (*Reporamphus australis*), the first ringed fish ever reported from Australian waters. As Fig. 3 shows, its body was encircled by a small rubber ring, which had evidently been on the fish for some time, since it had become white and had worn a groove in the belly of the fish. This ringed fish was put on record by Mr. Gilbert P. Whitley, the learned ichthyologist of the Australian Museum.

Rubber-Banded Needlefishes

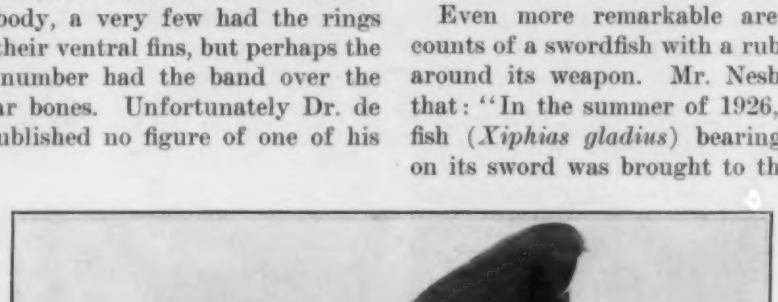
Professor Fernando de Buen, the Spanish ichthyologist, a valued correspondent in Madrid, has sent me an article recording in 1934 the occurrence of rubber bands on the Mediterranean needle-fish, *Ramphistoma belone*. This of itself is interesting, but one is amazed to read that between 350 and 400 such ringed fish were taken off the village of

—*Photograph by courtesy of Mr. F. E. Firth.*

FIG. 4. A HADDOCK WITH A RUBBER BAND.

THIS IS THE ONLY CASE SO FAR REPORTED FOR A FISH OF THE COD FAMILY. THE RING HAS MADE A CONSIDERABLE GROOVE.

Es Sòtil on the coast of Minorca, the easternmost of the Balearic Isles. The prodigious number of these fish thus adorned is simply astounding. Many of them had the band around the middle of the body, a very few had the rings behind their ventral fins, but perhaps the largest number had the band over the opercular bones. Unfortunately Dr. de Buen published no figure of one of his fish.



—*Specimen by courtesy of Mr. F. Specht.*

FIG. 5. A DOGFISH WITH A RUBBER BAND AROUND ITS NECK.
THIS SPECIMEN FROM MT. DESERT ISLAND, MAINE, IS THE FIRST RUBBER-BANDED DOGFISH EVER RECORDED.

A Rubber-Banded Haddock

Among other desiderata for this article, Mr. Firth has sent me photographs of a haddock (*Melanogrammus aeglefinus*) adorned like the first group of mackerel in the preceding section. This was taken in a trawl-net off Highland Light, Cape Cod, in water 35 or 40 fathoms deep in October, 1932. The specimen was not preserved. The band was around the head just back of the gill-covers, as Fig. 4 shows. It had apparently not afflicted the fish much, since it was taken alive. The photograph was unfortunately not made until after the fish had been dressed, hence it looks somewhat lanky—collapsed. This seems to be the only known case of a haddock with a band.

A Swordfish with a Rubber Band on its Sword

Even more remarkable are the accounts of a swordfish with a rubber band around its weapon. Mr. Nesbit writes that: "In the summer of 1926, a sword fish (*Xiphias gladius*) bearing a band on its sword was brought to the Boston Fish Pier. I examined the sword and personally removed the band from it. The band had cut a groove in the sword and had completely lost its elasticity." Mr. Dimick also writes that in 1926 or 1927 his attention was called to a swordfish in Boston with a rubber band around its sword. This was presumably the same specimen. Unfortunately no photograph was made.

A Sturgeon with a Band Around its Nose

Some years ago the North Carolina papers carried an interesting item about a two-foot sturgeon captured near Manteo, Dare County, in March. It was alleged that the snout of this fish about

two inches in front of the eyes was encircled by a rubber band. This was embedded in the bony and other tissues to a depth of about one fourth of an inch. No photograph was made, nor was the fish preserved. The newspaper account states that the band was cut off and the fish set free. In passing it may be said that it hardly seems possible that fishermen and a local newspaper correspondent could ever have heard of a case of this kind, or that they could have fabricated this brief account.

How Fishes Acquire Rubber Bands

The easiest and the most commonly accepted explanation is that fishermen have caught mackerel and other fishes and for a fake or a hoax have put rubber bands on them and have turned them loose. In some cases this is probably true. I have no doubt that sometimes some fishermen have done and even to-day do such things. But market fishermen on the mackerel grounds have other things to do besides slipping rubber bands on salable mackerel and putting them back into the sea.

A better explanation, in my judgment, is now to be offered. Rubber bands will float and they get into the seas in one of three ways. Thrown into the streets with other debris they are carried by rains through storm sewers into harbors. Or they are gathered by street cleaners along with other wastes, which are piled on scows, and these in turn are towed out to sea and dumped—as is the custom off New York. Or, in the third place, many such rubber bands are thrown overboard with other waste materials from steamships traversing the ocean.

Mackerel, bluefish, garfishes and needlefishes are all surface dwellers and surface feeders. These fishes nosing around will thrust their heads into the larger rubber bands which finally come to rest for the most part either just behind the head and in front of the pectoral fins, or when they slip over the pectorals they are arrested in front of the dorsal fin of the fishes. As the fishes grow larger the bands fit more tightly and cut grooves.

These bands, however, are found on small as well as on larger fishes, and for such I suggest this explanation. The young of mackerel, bluefish, garfish and needlefish, are found in harbors (unless the water is excessively polluted) swimming and seeking food around wharves. Here are likely to be found floating rubber bands of small as well as large size delivered by storm sewers. The little fishes push snouts and heads into these, as noted above, and thus acquire their bands. As the fishes grow up, the bands cut grooves in their bodies, and, since in these cold-blooded fishes regeneration goes on at an astonishing rate, the groove heals up below as fast as it is cut above and the band comes to rest rove through the body of the fish.

Dr. de Buen's rubber-banded fishes caught off a small island in the Mediterranean are difficult to explain. He thinks that the bands came from passing steamers. He does not state how great a stretch of time was covered in the collection of 350 to 400 needlefish thus adorned. One wishes for more data before attempting an explanation.

II. DOGFISH WEARING RUBBER BANDS AND A SHARK ATTIRED WITH AN AUTOMOBILE TIRE

Not only have various bony fishes wearing rubber bands been taken, but a number of dogfishes (small sharks) similarly adorned have been captured and photographed. And most remarkable of all, a fair-sized shark encircled with an automobile tire has also been photographed. These will now be figured and described.

A Dogfish with a Rubber Band

Early in July, 1931, Mr. F. Specht, the efficient collector of the Mt. Desert

—Photographs by courtesy of Mr. F. E. Firth.

FIG. 6. TWO YOUNG DOGFISH (*SQUALUS ACANTHIAS*) WEARING RUBBER BANDS. THE UPPER FIGURE IS OF A DOGFISH TAKEN OFF CAPE ANN, MASS., IN NOVEMBER, 1932. THE SHARK PORTRAYED IN THE LOWER FIGURE WAS TAKEN OFF THE MOUTH OF CHESAPEAKE BAY IN FEBRUARY, 1933.

(Maine) Biological Laboratory, made a most interesting catch. When he hauled in his trawl in Frenchman's Bay off Salisbury Cove, among the other fishes in it was a dogfish (*Squalus acanthias*) with a rubber band about its head—the only known case at this time of a dogfish so adorned. Mr. Specht, knowing of my interest in such specimens, very kindly sent this fish to me. Fig. 5, made from a photograph, shows both fish and band.

The band had slipped over the head of the fish but could not get past the broad wing-like pectoral fins. On the ventral surface of the fish, it has barely made a mark on the tough skin. On the dorsum, where there was probably more pull, it has cut a shallow furrow in the shagreen and epidermis, but in the region of the hinder gill-slits and the unprotected gills it has done its work. The last pair of gills shows considerable damage, but the others are practically unhurt.

THREE MORE DOGFISH WITH RUBBER BANDS

Mr. Firth has sent me his notes on three rubber-banded dogfish (*Squalus acanthias*) which he has seen. Two (measuring approximately 21½ inches each) were taken in November, 1932, in mackerel nets off Cape Ann, Massachusetts. Each of these had a rubber band around its head just anterior to the bases of the pectoral fins. The band had cut a groove in the flesh, as may be seen in the upper fish portrayed in Fig. 6, a photograph of one of the sharks noted above.

The third ringed dogfish of this species was a small fellow of only about 16 inches in total length. It was taken in February, 1933, in approximately 35 fathoms, about E. × S. of the Chesapeake Light Vessel, which lays about 12 miles out from the mouth of Chesapeake Bay. The lower fish shown in Fig. 6 is from a photograph of this small shark. Note the white spots so characteristic of the fish. Very clear also is the cut in the skin on

the back of what may be called the neck of the fish.

Here, then, are presented data for four dogfish (of the same species) wearing rubber bands. So far as I can say these are the first records of such banded dogfish.

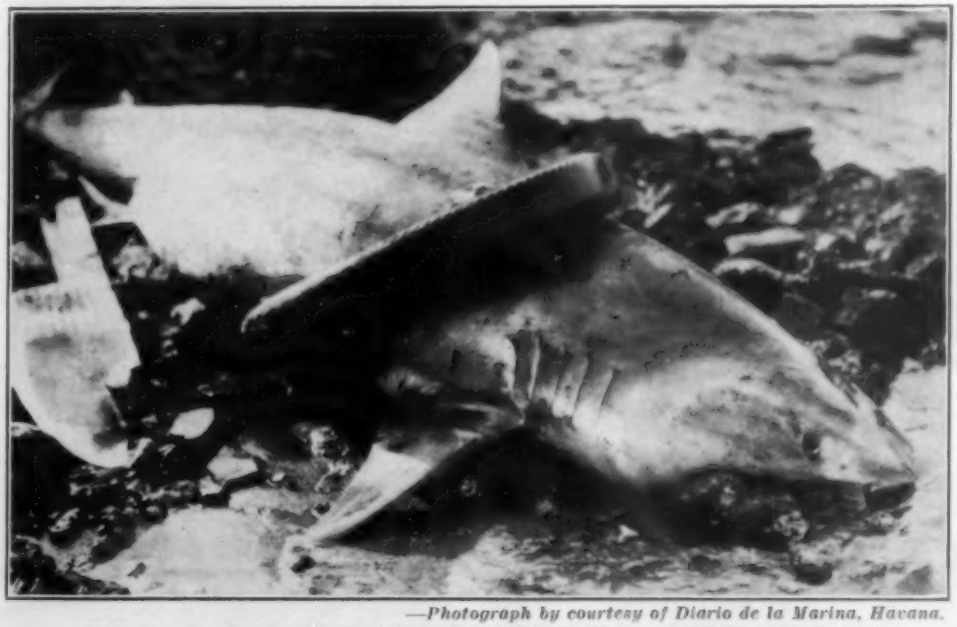
How Dogfish Become Banded

In the first part of this article, dealing with six kinds of bony fishes wearing rubber bands, I offered a tentative explanation for this phenomenon. The same explanation will apply to these small sharks. Street sweepings, debris and wastes of all kinds, including rubber bands, are loaded on scows, which are towed out to sea and dumped. These dogfish, probably when young, nosing around in the debris in search for something edible, thrust their heads into these bands. The bands were worked back onto the hinder gill-region, and later, as the dogfish grew up, the bands grew tighter and cut into the flesh.

A Shark Attired with an Automobile Tire

As Fig. 7 shows, we are now come to the most extraordinary ringed fish of all cited in this article—a shark wearing an automobile tire. Its history is as follows.

In 1930, a valued correspondent of mine in Havana, Cuba, Dr. W. H. Hoffmann, of the Laboratorio Finlay, sent me a clipping from the *Diario de la Marina* of September 21, containing the illustration (Fig. 7) and a brief account of the capture of this shark in the Bay of Cojimar, a small fishing village about five miles east of Havana. On request, the editor of the *Diario* courteously sent me a copy of the photograph but could give no data beyond that contained in the lengthy caption published with the figure. However, the indefatigable perseverance of Dr. Hoffmann led him to make a trip to Cojimar and to hunt up the captors of the shark and ascertain the facts from them and from those who saw the fish when it was brought to shore.



—Photograph by courtesy of Diario de la Marina, Havana.

FIG. 7. A SHARK WITH AN AUTOMOBILE TIRE AROUND ITS BODY.
It was captured in Cojimar Bay, east of Havana, Cuba, in 1930.

This shark was captured and brought in alive by two boys. They saw it out in the bay, fighting and lashing the water, and even trying to jump above the surface in its efforts to free itself. Seeing that the fish was helpless, the boys got a noose about it and thus ignominiously brought it to shore, where it was photographed. One observer told Dr. Hoffmann that the tire was so tight on the fish that one could see a ring which it had made in the flesh. This, however, is hardly confirmed by the photograph, wherein it appears that the tire has a certain amount of play. But the further statement of this man, that the tire was only removed by cutting the shark to pieces, is surely confirmed by Fig. 7.

How the Tire Was Acquired

It seems that, in Havana as in New York, street sweepings, garbage and all sorts of junk are loaded onto scows, which are towed out to sea and there dumped. Sharks are scavengers and they swarm at these dumping grounds to feed on the garbage. When a scowload of garbage was unloaded, we can see that our shark would dash forward and would nose about in it seeking what it could find to check its gnawing hunger. Just in front of the floating automobile tire, it smelled something edible. Clamping its big pectoral fins close to its sides to get them out of the way, I can see it as it drove straight ahead through the tire until its stiff unbendable dorsal fin fetched up against this. Fanning hard with its now free pectorals, it pushed forward hard to free itself from this strange encumbrance, which would not let go. Then came blind panic and it fought tire and sea as it was doing when the boys found it. Presuming that at least a day or two intervened between catastrophe and capture, we can understand that the shark, fighting the tire almost continually, unable to progress through the water and hence unable to procure food, would gradually grow weaker and weaker. And in the end, too weak to offer much resistance, it would suffer itself to be lassoed and towed to shore by the two boys.

When a brief note by Dr. Hoffmann and myself describing this fish was published, it attracted considerable attention and was abstracted and our figure reproduced in two journals of great circulation—*The Literary Digest* and *Time Magazine*. In this way it obtained wide publicity, and some interesting letters came in. One from a Texas man recounted how he and a friend had recently found on the coast of the Lone Star State an 8- or 9-foot shark stranded at low water in a shallow pool behind a sand bar. This shark they so easily mastered and killed by shooting that the letter writer suggested to me that "It would have been easy for us, had we had an automobile casing, to have put the same over the shark in the manner of that in your figure."

Having had considerable experience in fishing for and studying sharks at Beaufort, N. C., and at Key West and Dry Tortugas, Florida, I replied that I did not think it feasible even under the conditions under which they found their shark. For I know that, even the mildest mannered shark, when cornered, becomes as dangerous as a mad dog under similar conditions. In fact, in the light of my knowledge of and experience with sharks, I was ready unanimously to nominate my correspondent for the task of putting the ring (*i.e.*, the automobile casing) on the shark. Here let there be recalled the old story of the rats who wished to bell the cat.

HOW THE TAXONOMIST NAMES THE ANIMALS

By Dr. Z. P. METCALF

PROFESSOR OF ZOOLOGY AND ENTOMOLOGY, COLLEGE OF AGRICULTURE AND ENGINEERING, UNIVERSITY OF NORTH CAROLINA

ONE of the first steps in securing new knowledge or in advancing from old fields into the unexplored realms which constitutes the forefront of advancing science is the identification of the material with which we are dealing. In zoology this field is called systematic zoology. For many years this science was the most important one in zoology and commanded the best talents of the foremost zoologists of their times. More recently, unfortunately, systematic zoology has fallen into disrepute and the work of the taxonomist is belittled by the geneticist, the physiologist, the ecologist, the experimental biologist, the neurologist, etc. The work of the student of nomenclature is held to be unduly finicky and contributing only to the instability of an unstable nomenclature.

The following thoughts are presented to controvert these ideas, and, also, to present the thought that further progress in zoology in any field is dependent upon sound systematics. In addition, it is hoped that good students may be attracted to the field of systematics to help advance these ideals.

Before we proceed further it would seem worth while to call attention to certain fallacies which have grown up around systematic zoology. First of these is the belief that it is a static science. Nothing could be further from the truth. A careful review of the history of systematic zoology for the past century and three quarters would show that it has made a steady and consistent growth over that period, and one of the things I hope to point out in conclusion is that it will continue to grow and develop. This concept of a static systematic zoology is an outgrowth of the notion of a stable nomenclature which is another of the fundamental fallacies in the minds of many zoologists, including some systematists. There is no such thing as stable nomenclature. It is an illusion. And no substantial progress can be made until we unshackle the minds of the systematists from this handicap. Science is progress. Not a straight line progress but a zigzag progress, with here an advance and there a mistake. To concede that any branch of science is fixed or stable is stifling. Stable nomenclature is no more a possibility than a stable physics, stable astronomy or what not. Shall we ask the geneticist or the embryologist for a stable genetics or embryology? A stable atom almost relegated physics and chemistry to the plain of the dead languages. Any belief that stability leads anywhere but to extinction is erroneous.

Every once in a while we hear a cry that the systematist must return to the principles of Linnaeus. A person making such pleas has no conception of what this means. Perhaps he has never read a Linnean description, has certainly never attempted to fit such a description to any of the host of now known species. There can be no more return to Linnaeus in systematic zoology than there can be to Galton in heredity, to Von Baer in development, or to Balfour in physiology. Linnaeus worked with the limited and conspicuous fauna of Europe, supplemented by a few specimens of striking

animals from the then recently explored regions of the world. He had no conception of the hosts of species we now know to exist in all parts of the world.

Scientists, even including systematic zoologists, are like builders would be if they changed their plans constantly while erecting their walls. Is it any wonder that science has a crazy quilt effect? Only a very few scientific builders have really made substantial contributions to the structure as a whole, and no mind has as yet appeared great enough to conceive a plan of science as it should be. As far as I can see, the future will consist of a process of cut and try; discard and replace; trial and error; with a faith that, in general, progress is upward and forward. In this progress in the field of zoology, systematic zoology will contribute no small share, using, as it will, the same methods that are used everywhere else in science.

Systematic zoology is the only phase of zoology which makes a fetish of embalming its mistakes and then erecting these grotesque caricatures as totem poles along the way—totem poles to which each succeeding generation of students must do obeisance as they pass by. This leaves these totem poles as very conspicuous objects along the way and makes it possible for any one to ridicule the whole field of systematic zoology by pointing them out. But I said several years ago:[1]

> True, there is much in systematic zoology that is slipshod, but till statistics can be produced to show that the percentage of slipshod work produced by systematic zoologists is higher than in other fields of zoology, the writer of this article has a temporary residence in Missouri. He is of the opinion, also, that as great a percentage of the work of the systematic zoologist will stand the test of time as the work of the anatomist or any other worker in the field of zoology and proposes to remain of that opinion until time, the great leveler, proves to the contrary.

[1] Z. [P. Metcalf], *The American Naturalist*, 53: 282–288, 1919.

Linnaeus is apparently not the only genius that has left the back door open and that has "been followed by a crowd of other workers eager to attain to immortality," as witness the great mass of half-digested literature on genetics, say, that has been crowded into the past ten or a dozen years. It would be a sad state of affairs indeed if systematics as a whole were not improving. That there have been occasional backward steps there is no doubt, but on the whole the progress has been forward.

It may not be amiss to call attention also to the fact that there can be no substantial progress in any field of zoology unless it is based on sound systematics. I use sound advisedly, meaning of course in a purely relative way; sound for the time being or temporarily at least; a stepping-stone to something better; without implying, I hope, that any modern scientific Peter is going to erect on this foundation a great permanent edifice of modern science.

Systematic zoology, as I perceive it, consists of three main fields, taxonomy, nomenclature and phylogeny. These fields are constantly playing upon each other and being played upon by other fields of zoology and by other sciences. Discoveries elsewhere change our systematic concepts, and changes in these concepts bring about still further changes. Perhaps we should attempt to define these fields as well as we can with our present knowledge. These terms have not always meant precisely what I shall attempt to make them mean here, but since so much of science is definition, it seems worth while to limit our words as much as possible and attempt to give to them a narrow meaning. There are of course no hard fixed boundaries between these fields. The definitions here proposed are merely an attempt to throw certain aspects of systematic zoology into bold relief.

Taxonomy deals with the descriptions and illustrations of all the prime groups of the animal kingdom. Nomenclature

is that field of systematic zoology which is concerned with the names we use for animals but not with the animals themselves. Phylogeny is that branch of systematic zoology which describes the evolutionary descent of organisms and their arrangement into some sort of system to show these relationships. Now obviously these various fields are closely related and interrelated so that a change in one must affect the others. The description of a new genus, the segregation of a new family or order will profoundly affect the field of phylogeny. The proposal of any new taxonomic group will necessitate new descriptions and a rearrangement of certain areas of our phylogenetic tree. Each of these major fields of systematic zoology is important enough for further consideration.

The true basis for all systematics is the description and the illustration, especially the descriptions and illustrations of those two prime groups in taxonomy, the genus and the species. Descriptive science is an art in itself. Many models, good, bad and indifferent, are extant. Descriptions are not necessarily complete in all details. One of the best earmarks of a good description is that it should be revealing. If it is too detailed, it may conceal the true characters. It is worth remembering, however, that what may be considered a complete description to-day may be considered very incomplete to-morrow. All taxonomists have had the experience of trying to correlate the descriptions of several authors only to find that these authors have not used the same sets of characters. In this connection it should be stressed that what are considered important generic or specific characters by one generation may be discarded by the next. Thus one generation of Homopterists stressed head characters and venation and the next stresses the internal phallic characters. The best plan is, perhaps, to take a standard text-book of morphology and make a complete and systematic list of all morphological units. If this list is used, it will enable the systematist to stress the important characters and at the same time be reasonably sure that nothing of importance is missed. If this list is arranged by placing the most important regions closest to the left-hand margin and those of less importance to the right and finally those of least importance furthest to the right in a series of inverted steps, one may determine at a glance how far it is necessary to proceed in any given case.

Illustrations are a universal language that needs no interpreter. That they are not more used in systematics is due to the belief that they are difficult to produce and expensive to reproduce. These conceptions are false, however, for if illustrations are reasonably carefully made, they tell more per unit of measure than the printed page can tell. Another reason that illustrations are not more frequently used is the belief that they can be made only by artists. Any one who can learn penmanship can learn to draw, penmanship being of course a rapid kind of drawing. While a few of us may achieve a penmanship that would be the envy of an engraver, most of us write so atrociously that even our private secretaries get a headache trying to decipher it. Not all of us will be finished draughtsmen, but if any one will put the same amount of time on learning to draw that he devotes to mastering the rules of grammar, punctuation, rhetoric and penmanship, he will be able to make creditable drawings which will aid those systematists coming after to better interpret their meaning.

Neither should it be implied that there is any such thing as perfection in either descriptions or illustrations. This should not deter us, however, from striving towards perfection. I do not mean to

imply that it is easy to make an illustration of a tridimensional object in two dimensions. The only real illustrations would be plastic reconstructions, and as yet no one has devised a simple method of doing this or of reproducing the models, even if they were constructed. Neither is descriptive writing easily attained. It is in fact one of the highest of the human arts, and can only be approximated by constant striving. And even if perfection in descriptive science is attained, it can be destroyed by bad interpretation.

Comparisons in descriptive systematics are valuable, but may easily be overdone. Comparisons also may lead to curious results. My attention was recently called to an interesting case. Three American entomologists have recently described new species in a certain genus, each comparing his species with a species described by that great early American systematist, Say. A fourth entomologist, on reviewing the genus, made the interesting discovery that each of his confrères had an entirely distinct species in mind, as the species described by Say. Such illustrations emphasize the need for frequent revisions of considerable groups covering an order or family, at least, so that future taxonomists may make substantial contributions to science.

Keys are the acme of systematic zoology. If they are properly made, they are a guide not only for the neophyte but for the mature student. Simplicity and lucidity should be the guiding principles in the construction of keys, but no matter how carefully keys are made the user must take every precaution in using them. In other words, there are no foolproof keys. Keys should also be so arranged that they may be used backwards as well as forwards. The reverse use of a key will often throw errors into bold relief. Keys should be well illustrated as an aid to the short descriptive phrases of the key. These illustrations may be placed on the same page as the couplets of the key,[2] or the illustrations may be grouped on plates and numbered for easy cross reference.[3]

Keys should always be arranged in contrasting couplets. Multiple choice is confusing to a white rat in a psychologist's maze; but it is confusion worse confounded in a systematic key. Many different arrangements of the couplets have been used. For the most part these may be grouped into four kinds: (1) keys with couplets in juxtaposition;[4] (2) keys with indented couplets;[5] (3) keys with grouped couplets;[6] and (4) a combination key.[7] Each of these types of keys has its advantages and disadvantages and it might not be amiss to discuss them briefly.

The first type of key is easy for the beginner to follow, as the two contrasting members of the couplet are close together and it is easy to comprehend the implied differences. It is also economical of space. One of its chief disadvantages is that it is not easy to use in reverse order. The other great disadvantage is that it is not easy to comprehend the groups that fall under each couplet. This is not a serious disadvantage if the key is purely artificial, but this type should not be used to display phylogenetic relationships.

The indented type of key has one very important advantage, that is, it sets out the groups very conspicuously. It is easy

[2] Z. P. Metcalf and C. L. Metcalf, "A Key to the Principal Orders and Families of Insects," 3rd Ed., 1–23; figs. 1a–225b, 1928.

[3] Z. P. Metcalf, *Jour. Elisha Mitchell Sci. Soc.*, 38: 139–230, pls. 38–70, 1923.

[4] *Idem.*

[5] J. H. Comstock, "An Introduction to Entomology." Complete edition; xi–1044; figs. 1–1228, 1924.

[6] F. Muir, *Proc. Hawaiian Ent. Soc.*, 5: 205–247; pls. 4–8, 1923.

[7] Z. P. Metcalf and G. Horton, *Lingnan Sci. Jour.*, 13: 367–429; pls. 37–43, 1934.

to use in reverse. It has the great disadvantage that it is uneconomical of space, especially in a long key. It is difficult to set in type and, if it is long with one member of the couplet on one page and the other on a succeeding page, it is very difficult to use.

The third type of key has most of the advantages of the indented type of key, although the contrasting characters are not as conspicuous. It is economical of space and it is easy to use in reverse. Similar organisms are of course closely grouped together. It has one of the chief defects of the indented key: if the key is long, members of a couplet may be separated so far on the printed pages that it will be difficult to follow.

A consideration of these various defects led the author to devise a combination key in an attempt to take advantage of all the good features of the other three types of keys and in so far as possible to eliminate most of the undesirable features. This type of key may consist of a combination of the indented type of key with either a key with couplets in juxtaposition or a key with grouped couplets. In any event the key is made up as follows: The primary, secondary and tertiary characters, in a long key at least, are indented; the following couplets are placed in juxtaposition, as in the first type, and appropriately numbered, or grouped, as in the third type. Personally I am inclined to the former method, for this places the minor characters close together, where they may be more readily interpreted. This type of key has many advantages, it seems to me. It is fairly economical of space. The major groups are clearly outlined, and since these are the more important it is fairly easy to use in reverse.

KEY TO CHINESE AND JAPANESE SPECIES OF EOSCARTA

A. Tegmina with base pale, apex black, bicolored.
  B. Tegmina red at base ..... *seminiger* Melichar
  BB. Tegmina ochraceous yellow clouded with black at base ..... *seminiger* var. *crocea* Metcalf and Horton
AA. Tegmina not bicolored.
  B. Tegmina uniformly colored.
    C. Head and pronotum pale yellow or reddish ..... *borealis* Distant
    CC. Head and pronotum dark brown or black 1
      1. Abdomen black 2
      1. Abdomen reddish brown basad. Legs brownish ..... *karschi* Schmidt
      2. Crown not as long as broad. Abdominal segments bordered with yellow. Legs black ..... *assimilis* (Uhl.) Matsumura 1903a: 18 (Japan)
      2. Crown as long as broad. Abdominal segments not bordered. Legs brownish yellow ..... *fusca* Melichar
  BB. Tegmina not uniformly colored.
    C. Tegmina black with two yellow spots near the apex, one on the costal margin, the other at the apex of clavus ..... *bimaculatus* Matsumura 1907b: 106 (Formosa)
    CC. Tegmina not black with two yellow spots 1
      1. Tegmina orange red with small black spots in the apical cells ..... *laoensis* Schmidt 1918a: 203 (Tongking)
      1. Tegmina variously colored 2
      2. Pronotum uniform brownish yellow ..... *aurora* Kirkaldy
      2. Pronotum not uniform brownish yellow 3
      3. Abdomen blackish, shading to reddish basad, segments bordered with red ..... *melli* Schmidt
      3. Abdomen dark brown, segments not bordered 4
      4. Length 4.0–5.0 mm. ..... *assimilis* var. *apicalis* Matsumura 1903a: 18 (Japan)
      4. Length 7.0–10.0 mm. ..... *zonalis* Matsumura 1907b: 106 (Japan)

A brief description of my present method of making keys may not be amiss. A survey of the material usually reveals some contrasting characters by means of

which the material may be divided into two groups. These contrasting characters are then taken as primary couplets. The two members of the couplet are then numbered 1. and 2. and typed on 5×8 cards in order that they may be filed in the standard 5×8 card drawer. The names of the species that fall under 1. are then written on this card and likewise for 2. These primary groups are then divided into secondary groups with their characters written on separate cards and numbered 1.1 and 1.2 and 2.1 and 2.2, respectively. So with tertiary, quaternary and all other groups to the end. By this method it is easy to use the key, to discover its defects and to remedy them by minor corrections on the cards, or to discard a couplet substituting a new and better couplet; to raise or lower the rank of a couplet; in fact, to make any change whatsoever, without completely destroying what has been done and making a fresh start.

Nomenclature

Nomenclature as defined above has to do with names alone. It does not determine whether a genus or species is valid, but it does determine what name should be used for any given unit of the Animal Kingdom.

Nomenclature or the determination of valid names is based on laws. All laws are based on precedents and frequently run counter to common sense, whatever that is. Hence, the law does not always seem to be sensible. Not infrequently zoologists who have made no study of nomenclature want to overthrow not only the results of the study of nomenclature but even the laws thereof. Such actions must be condemned. Laws should be not only the results of precedents but should also be the outgrowths of experiences.

The laws of nomenclature are not many. They have an honorable history and are the results of the ripest experience of some of our best systematic zoologists. They should be followed, therefore, until there is common concurrence that they can be improved. These laws of nomenclature have to do principally with the forms of generic and specific names and names of other groups; with what constitutes publication and with priority of publication. Most of them are simplicity itself. They are, however, not always applied with wisdom, hence the confusion that arises.

These laws must not be *ex post facto*. To make them retroactive would destroy nomenclature entirely. Let me illustrate. We pass a law making the designation of genotypes one of the prime requisites of the description of a new genus; if we made this retroactive fully half of the generic names now in use would be invalid. Occasionally we hear proposals made which would not stand the test. Suppose, for example, we were to suggest that all names not accompanied by adequate descriptions of the things which they are supposed to designate shall be discarded; nothing could be fairer, but immediately the question arises, Who shall determine what is an adequate description?

There are two other functions of nomenclature which may be easily overlooked: The preparation of standard bibliographies and the preparation of catalogues. The size of these tasks may be appreciated best by some concrete examples. I estimate that the insects known as the higher Homoptera constitute about one-five hundredth of the species of the Animal Kingdom. The bibliography for this group comprises more than 8,000 titles which have been published in at least 1,000 separate books and 900 different magazines. The card cataloguing and collating of this material is no small task.

The task of cataloguing this material is so vast that it is doubtful if one generation can possibly catalogue the material for the next generation. The group

Homoptera has perhaps 3,100 known genera and, it is estimated, about 20,000 species. To publish complete catalogues of this group alone would involve about 20 volumes, each of at least 1,000 pages. And this represents the accumulations of less than 200 years. Shall we raise the question, "What of the future?"

Another function of nomenclature is to define the fundamental units of the Animal Kingdom. If this definition is accepted, we may realize how much work there is yet to be done in the field of nomenclature when we attempt to get from a group of zoologists a definition of the concept species. Yet the very attempt to define such concepts is worth while, and the contributions that nomenclature can make to both taxonomy and to phylogeny by making this attempt are valuable.

Linnaeus had in mind only four taxonomic concepts. The genus and species were the most important, but in addition he had higher groups than the genus, which we may call orders, and lower groups than the species, perhaps best designated by the name race. Let us be clear, however; Linnean taxonomic concepts are to be compared with modern taxonomic concepts by courtesy only. Linnean genera, for example, are more nearly of the rank of modern superfamilies. His species are of specific rank only in those cases where a region is inhabited by a single distinct species of a genus. Linnean species are, therefore, more nearly of the rank of genera. And his so-called orders are really classes or groups of modern classes.

Modern nomenclature recognizes no less than sixteen categories, ranging from kingdom to individual. Each of these is elevated or depressed by adding the prefixes super or sub, so that in reality there are more than thirty grades of taxonomic concepts. Each of these grades is of use not alone to the systematist and phylogenist, but to the general zoologist. It is too bad that there is not a thoroughgoing recognition of this idea by the morphologist, embryologist, geneticist and workers in zoological fields other than systematic zoology. Most of the morphology, or what not, is not the morphology of a given species but of a family, a tribe or even an order. If this idea was generally accepted, the worries of the systematic zoologist and of the zoological worker in other fields would be largely eliminated. The specific or generic position of most of the material handled by the general zoological worker is not of prime importance, and it will not be until we have a firm foundation of the morphology, let us say, of the orders. Morphologists of future generations may concern themselves with the family, the tribe, the genus or the species. If the work is well done, it will take at least several centuries for the morphologists to take each of these steps, and by the time morphologists are working with species the taxonomist will have developed new refinements of techniques, so that the race or form will be elevated to prime rank and the species will no longer be of importance.

The taxonomic categories which have been proposed may be arranged to best advantage in the form of ascending steps.

TAXONOMIC DIVISIONS OF THE ANIMAL KINGDOM

KINGDOM
Branch
Series
PHYLUM
Division
CLASS
Legion
ORDER
Cohors
Phalanx
FAMILY
TRIBE
GENUS
SPECIES
Variety
Individual

Obviously, if we could gain a toehold anywhere on these taxonomic steps, we could climb upward or downward, as the case may be, to the groups of greater or lesser rank. But this is difficult to do. The top step, Animal Kingdom, and the bottom step, the individual, are generally accepted. No attempt is made to define them, so far as I am aware, save by philosophers, who should know better, and by inmates of state hospitals, who know no better.

Let us, therefore, without fear that we may stub our toes going up or stumble going down, attempt to define three of these prime groups, the species, the variety and the genus. I am under no illusions that these definitions will be accepted even by the majority of systematic zoologists. If they were thus generally accepted, they would be so innocuous that they would be meaningless. If we can get a definition with which men will come to grips, there is some hope for taxonomy as a science.

A species is a prime group of animals which reproduces its like in nature. A variety is a digressing geographic or ecologic group reproducing individuals which are constantly similar to, yet consistently atypical of the species. A genus is a group of species with outstanding characteristics which are recent descendants, in a phylogenetic sense, of a common fossil ancestor.

Now, having dutifully accepted these definitions, or cast molds for better ones, we can climb the taxonomic steps with the utmost ease. And definitions for tribes or families or any other taxonomic group may be constructed. We may likewise speak of subtribes and superfamilies as if they were real entities and not merely the figments of an imagination too deeply involved with boxes of dried insects, or cases of mollusk shells in the dusty attic of some great museum.

Phylogeny

Phylogeny is that branch of systematic zoology which describes the evolutionary descent of organisms and their arrangement into some sort of system to show these relationships. I know of no field of zoology requiring such a broad philosophic grasp of fundamentals, such thorough scientific bases and at the same time such an imagination as that required of the real phylogenist. Let us examine the reasons for this statement.

Phylogenetic relationships are usually shown in the form of family trees. These of course are pure artifacts due to our limitations of a two-dimensional printed page in a three-dimensional world. The facts are, that for phylogenetic purposes we need a four- or five-dimensional space, perhaps a multiple dimensional space. For present purposes it is enough for us to comprehend the difficulties of the construction of our two-dimensional phylogenetic tree. For purposes of illustration, let us assume that we had never seen a tree of any kind. We know nothing of root, trunk, limbs, branches, twigs or leaves. With this lack of knowledge, some one dumps on our laboratory table a cart-load of leaves of all kinds and we are told to sort out the oak leaves from all other kinds and to reconstruct a particular oak tree, root, trunk, limbs, branches, twigs, and to place each leaf with its petiole on the correct twig, with each twig branching at the proper point, with branches in proper relation to all twigs and to the main limbs, and finally with limbs symmetrically arranged on the trunk. If you can comprehend such a task, you can catch the vision of the task confronting the phylogenist who attempts to reconstruct the phylogeny of a group of animals. If I were to ask you to reconstruct even the main limbs of the oak tree that grows by your garden gate, which you have seen each morning and each evening as you hurry about your

daily task, you would say that it is impossible.

The size of the task, however, shall not deter us. We will struggle with the problem, and each advance in every other field of zoology will cause us to shift a branch here and there; to place two leaves on this twig where only one grew before; to erect families and superfamilies; to merge and combine genera and species.

The relations between phylogeny and morphology are perfectly obvious. But the refinements of the morphologist have outrun the phylogenist. Elsewhere[8] I have pointed out the relation between zoogeography and phylogeny. The relation between embryology, development and phylogeny has lagged because the old phylogenetic law has fallen somewhat into disrepute. The trouble was not with this law, but with the statement of the law, "Ontogeny repeats phylogeny." If the law is restated, "Ontogeny *reveals* phylogeny," it takes on new meaning and opens a new continent to discovery and exploration. No one really meant to imply that an organism in its short embryonic development covering a few days or weeks could possibly repeat the stages of its racial history, covering untold centuries. If we really knew the ontogeny of any group of animals, we would have a photograph, perhaps somewhat dim, of our hypothetical phylogenetic tree. Therefore, I believe, I am safe in saying that the next great advances in phylogeny will be made in the area of embryology and development which has been thoroughly correlated with morphology and zoogeography.

History

Systematic zoology has a long and honorable history. As a matter of fact, like political history its beginnings are shadowed in antiquity. Primitive peoples everywhere gave names to the animals around them, and a study of these names will always show a primitive understanding of relationships. Aristotle summarized the knowledge of his day with his scheme of classification, and thus matters stood for more than twenty centuries.

The next great contribution was by John Ray, the Englishman, before 1700. This was the fundamental concept of the species. It was followed soon thereafter by Linnean binomial nomenclature in the middle of the eighteenth century and by the phylogenetic concepts of Lamarck at the beginning of the nineteenth century.

Around and through these three great concepts has been erected modern systematic zoology, with its great museums, with marvelous collections and their trained staffs of specialists in all groups of the Animal Kingdom.

There are also four periods of systematic zoology which are worthy of recognition, for they help to explain the present condition: A primitive period extending down to about the beginning of the eighteenth century; a period of expansion, from about the beginning of the eighteenth century to the early years of the nineteenth century; a period of exploration, beginning with the nineteenth century and extending to about the middle of that century; and lastly, a period of specialization, beginning before the middle of the nineteenth century and extending to modern times. These periods must not be thought of as distinct entities separated by cataclysmatic revolutions; but as periods which merge into each other so gradually that it is, of course, impossible to give exact dates for their beginnings and endings. Each period was the outgrowth of the period that preceded it. Before one period vanishes, another is gradually growing

[8] Z. P. Metcalf, *Jour. Elisha Mitchell Sci. Soc.*, 49: 97–107; figs. 1–4, 1933.

until it overshadows that which has gone before. Thus we could not have a renaissance in human thought and human science without men becoming dissatisfied with the primitive names which were given to animals. Out of this dissatisfaction grew Linnean binomial nomenclature and a desire to name all the animals in the world. Hence, the old primitive notions faded out during the eighteenth century, and Linnaeus and his pupils attempted to name the animals from all parts of the world, sometimes from actual specimens, sometimes from the tales brought back by explorers of remote regions of the world.

Gradually there dawned in the minds of systematists of this period the idea that perhaps all was not what it seemed; perhaps some of the tales were overdrawn, that dragons were not rampant in the remote regions of the world. On the other hand, there was perhaps the notion that there were as good fish in the sea as had ever been caught. So gradually expeditions were sent out, and we had a period of exploration which culminated in the great expeditions which contributed so much to our knowledge of the Animal Kingdom of the world.

When this mass of material commenced to flow towards the centers, there developed a period of specialization. Men were no longer systematic zoologists, but became specialists in restricted areas. They were mammalogists, ornithologists, herpetologists, entomologists, conchologists, or what not. Soon there were no entomologists, but coleopterists, dipterists, lepidopterists, each with his own techniques, his own language, his own special tribal ceremonies.

To-day the tendencies are toward narrower and narrower fields. This is as it should be. The wealth of material, especially among the less conspicuous insects in the tropical regions of the world, is absolutely beyond belief. The size of the task confronting systematic zoologists is hardly appreciated, even by the systematists themselves.

Perhaps we may appreciate the growth of systematic zoology by a few contrasts. One hundred and seventy-five years ago Linne wrote the 10th edition of the Systema Natura. It was a small volume of 821 pages containing the descriptions of all the animals then known, arranged in 312 genera containing about 5000 species. The insects of the Order Homoptera were included in one genus with 42 species and occupied 5 pages or about 1/165 of the whole work.

What of today? The same group is arranged in 2 Cohors, 11 Superfamilies, 34 families, 65 subfamilies, about 3100 genera and I estimate about 20,000 species. And the end is not yet. I never receive a collection from the tropical regions of the world, be it Cuba, Central America, Colombia, Surinam, Brazil, West Africa, East Africa, Madagascar, Java, Philippines, or New Guinea in which the new species are not numerous. And of this group these regions have never been systematically collected.

But to describe completely these 3100 genera and 20,000 species would require at least 200,000 pages or 250 volumes the size of the Systema. To describe the Animal Kingdom assuming that the Linnean proportion holds would require 165×250 volumes of 800 pages or 41,250 volumes. Perhaps I should not, but I must of necessity, remind you that as carefully as I can estimate the Homoptera represent not 1/165 of the Animal Kingdom as Linne had it but about 1/500. Our library of Systematic Zoology contains not 41,250 volumes but 125,000. Comments are superfluous.[9]

Future

What of the future? Well, the life of a prophet is easy. If the prophecy comes true, he can always say, "I told you so." If it fails, no one remembers. I am reminded of the famous Mother Shipton's prophecies. Every one remembers, "And carriages without horses shall Run." But every one has forgotten the next member of the couplet, "And the world to an end shall come in the year Eighteen Hundred and Seventy-one."

With this as a background, I do not hesitate to prophesy that systematic zoology will come into its rightful place

[9] *Idem.*

again in the sisterhood of zoological sciences. That it will be more closely correlated with the other branches of zoology. That there will be closer relationship among the branches of systematic zoology, nomenclature, taxonomy and phylogeny. But that there will be also a much greater interplay between systematic zoology and morphology, embryology, genetics and zoogeography than there has been in the past. Advances in these sciences will be reflected more quickly than at the present. This ideal can only be attained if the great bibliographic services like the *Zoological Record* and *Biological Abstracts* are not only maintained but expanded. It can not be attained, however, if we do not have a careful reworking of the accumulations of the last two centuries. Especially must we have comprehensive bibliographies of family or larger groups so that it will not be necessary for each student to traverse the same road. Complete catalogues must also be published, so complete in all details that the chances of improvement will be so slight that students will turn their eyes to the future and not to the past. And lastly, we must have comprehensive reviews by continental areas of the larger groups of the Animal Kingdom; so detailed and so well illustrated that he who runs may read and so simple that the beginner may comprehend.

As specialization increases, as the problem of publication becomes more acute, there should be formed somewhere an international exchange for reprints. Such an international exchange would receive subscriptions from workers for reprints in their specialties and authors or journals would send sufficient reprints to fill the subscription list with a reserve for future demands. Such a service would be of immense value to systematic zoology and the difficulties in the way of its establishment are not insurmountable.

This is a gigantic program, and there is in it nowhere a place for a static science. Things that are alive must grow.

MUTUALLY INTERPRETATIVE RELATION BETWEEN HUMAN AND AVIAN NATURAL HISTORY[1]

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WHY do I use the antiquated term natural history instead of the thoroughly modern term biology? Because I want to emphasize the truth that natural history is antiquated if being alive is antiquated, and not otherwise.

Were the word biology to be used in the original meaning of its Greek ancestor it would mean almost exactly what natural history meant as used by two of the greatest students of animate nature that have ever lived. I refer, as probably most naturalists would surmise, to Aristotle and Charles Darwin.

The meaning in common of the two terms was "way of life." With the Greeks *bios* meant the way of life, especially of men, but also of animals generally. It included birds rather specially it would appear from the famous play, "The Birds," by the great comic poet, Aristophanes. And with Aristotle natural history meant way of life of animals generally but included man rather specially, as shown by the great place man has in his "Natural History of Animals."

Now way of life is first and foremost way of acting—way of doing things. It is behaving. It is conduct. And particularly significant is the fact that this implies individual organisms, each composed of many parts so related with one another that the individual is able to act by means of its parts in such fashion as to meet its own necessities, inclinations and desires. The separateness of every individual from every other is manifest in the fact that each one must act by means of its own parts. No individual can act by the *direct* means of the parts of any other individual. No one breathes or talks by means of the lungs and mouth of somebody else.

Originally and fundamentally, then, both natural history and biology meant and really always must mean the mode by which individuals act so as to continue their existence as living bodies and to continue the existence of the race or species.

Foundational therefore to all knowledge of the living world (and for that matter of all the world) are individual bodies so organized as to be alive. And, strikingly enough, among these bodies are the very ones that do the knowing! So it falls out that among the ways of life of certain of these bodies is learning and knowing the very subjects we name natural history and biology. Let us come down to the business in hand, that of men and birds.

We are all vertebrates; no room for intelligent question about that. This is only another way of saying that we are all built on the same ground plan. For this occasion it is enough to notice only two items in this plan: our two pairs of limbs and our heads.

Although the grossly obvious limbs of men and birds are extremely unlike in many anatomical points they are unmistakably alike in many other points. Hardly any thoughtful person can fail to be impressed by this two-fold truth.

[1] Modified from a paper read at the annual meeting of the Cooper Ornithological Club held in Berkeley on April 16, 1937. It is a sort of epitome of portions of two books by me: "The California Woodpecker and I" a study in comparative zoology (now in press); and "Nature in the Light of Science, Art, Philosophy, and Religion" (nearly ready for the press).

So likewise as to heads. No one can avoid taking some notice of the fact that a bird has two eyes, two ears and a mouth in its head no less truly than has a man, despite the great difference in general shape and get-up of the two heads.

But what is specially to the purpose in this disquisition is comparison of the way men and birds use the parts under consideration—how the members are utilized by their possessors in their ways of life. In their typical mode of locomotion birds so far outstrip us humans in our typical mode that we never pretend to be in their class. Their way of life, in which their fore limbs play such an essential part, gives them an enormous advantage over us as judged by the same criterion. What plodders we humans are when we go a-foot, as compared with birds when they go a-wing!

But exceedingly important as is travel for both birds and humans this is far from the whole story. Both must do many other things in order to keep on living and living as they like to live. So we turn to the other anatomical member under consideration, the head, and reflect a bit on the use birds and men make of this member in their respective ways of life.

Perfectly obvious, is it not, that both use it to several common ends? For instance, the fact that in both the mouth is in the head makes it inevitable that the head should be extensively utilized by both for eating, to say nothing of other activities involved in the nutritional business. Then there is the utilization of the mouth by both in the production of sound —of vocalization. The importance of this to both, but especially to humans, far surpasses, from one point of view, its importance in eating and breathing. Reflect, also, on the extent to which both manipulate their eyes in seeing by means of the head-neck combination. Herein birds are specially expert in several respects.

Now comes a matter that, although it has received much attention from some directions, has never, so far as I know, received enough or of the right kind from any direction. I refer to the principle of correlation among the parts of an individual animal. While the principle applies to almost if not quite all the myriad parts (including the cells) it is specially obvious and important as between the head and the fore limbs of the higher vertebrates—the very parts that force themselves upon our attention in this study. Surely no one needs reminding of the way a bird uses its head and wings cooperatively—except, perhaps, as a reminder of how much more extensive and nice the cooperation is than in cursory notice one takes account of.

As for the way a human uses his head and fore limbs cooperatively—well, let anyone keep a record of all his movements for a busy day and see what fraction of them falls into the class of head and arm-hands cooperation. No one could fail to be impressed by such a study—if he never was before—with the extent to which not only his way of life but his life itself are dependent on this combination of these anatomical parts, and on his activities by means of them.

Indeed so obvious are the ways of life of us humans dependent upon the cooperation and coordination of these members, especially if any skilled hand work is involved, that we take it as a matter of course and pay little or no attention to this portion—the strictly psychobiological principles involved.

But there are other vital principles involved that are far from obvious to common experience, and so enter very little or not at all into conscious knowing and thinking by the vast majority of persons. I refer to the great question of how we mortals and birds come to be the possessors of parts so remarkably related to and cooperative with one another. The question divides into two distinct portions. One portion is that of how the relation comes to pass in the development of the individual—human, bird, lizard,

frog, fish or any other member of the vertebrate phylum. The intricate sciences of embryology and genetics struggle with this portion of the question and have gained much information concerning it. What is more, they have secured a good deal of real understanding in connection with it.

The other part of the question is that of how the individuals not merely as such, but as members of races, come to have parts thus correlated and cooperative. Paleontology is the chief science which gathers specially relevant facts for the struggle with this question.

An enormous accumulation of facts of both anatomy and physiology enables students to conclude that the coordinativeness and cooperativeness of the parts of an animal must be in its nature at the various stages of its *individual development* and of its *racial development*, as well as in its nature as shown in those activities that make the individual alive or living.

Observations on the anatomy and physiology of animals now living and observations on the anatomy of animals long since dead, both individually and racially, and reasoning on all the sense data in accordance with Aristotle's principle of complete reality (*entelecheia*)[2] seem to compel us to conclude that just as we must, and in practice actually do, accept the living individual animal (especially our consciously knowing individual selves) as a whole at any particular *moment*, so we must accept the individual as a whole (a complete reality) throughout *all the moments* of its life. A particular bird is as truly a living reality at the moment of hatching, say, as at any other time during its life, including the moment just before the depredator's fatal wound or the hunter's fatal shot. So likewise as to a particular human. Its real aliveness is not limitable to any single moment for the sufficient reason that it is involved in the aliveness of a great host of parts having different rates of vital action. For example, the rate of "flow" of a nerve current is very different from that of the blood current, yet both are essential to the vital existence of a bird or a man. That the sciences of living nature are being driven to such a conception under the designation of organicism, is, I think, beyond doubt.

[2] W. D. Ross, "Aristotle Selections," Glossary. 1927.

Although racial development (evolution of the most usual meaning to-day) is somewhat more difficult to interpret from this standpoint, it must, I am quite sure, be so interpreted. Thinking about evolution always presupposes a racial line, or line of descent. Nor is there anything known to science for such a line to be composed of except individual organisms, capable of maintaining themselves in the living state and of propagating their kind. Mr. Darwin's constantly invoked idea of "descent with modification" and the French evolutionists' idea of transformation are meaningless generalities as applied to living nature as a whole, except as they envisage uncountable millions of individuals composing the ancestral line of each and every individual now living. And not only that: every one of these ancestral individuals must be envisaged as composed of many parts essential to their individual existence and through which modification and transformations new kinds of individuals have been produced.

Every individual in the ancestral line of any kind of modern birds (of my woodpeckers, for example) in its long course back to its presumed reptilian ancestors must be imagined as possessing two pairs of limbs and a head modifiable in the direction of those actually possessed by the birds of to-day.

So far this imaginary picture contains little beyond what the orthodox evolutionary picture contains, but now comes a point that the orthodox picture does not contain in any truly kinetic sense: every one of those ancestors must have

depended for its aliveness upon using its limbs and head cooperatively no less than does its descendants of to-day. One of the major implications of this brings the principle of correlation of parts into the racial life to correspond with its application in the individual life. For another thing, it implies that as to parts in which the correlation is most vital for the existence of the individual the existence of each part so related is dependent on the existence of its correlate. It implies that the bird's head as such would not exist except for the existence of the bird's limbs as such. Since in the case of birds the mode of locomotion is the most definitive quality in their way of life, we are bound by the logic of the general problem to consider with special care the body parts most concerned, not only as to the structure and function of the parts in birds of to-day, but as to the modifications and transformations that have taken place in the ancestral line to produce these parts. Despite the enormous mass of observational evidence now available from anatomy, physiology and biochemistry, that it is in the very nature of a living body to consist of mutually dependent, interacting parts, when the question of how the body comes to be thus composed, very many moderns (seemingly most analytic students, particularly if their specialty happens to be genetics) are in much the intellectual state on this matter as was old Empedocles. For him, recall, the parts of a living body come together "not all at once, but coming together at their pleasure, one from this quarter, one from that."[2] While it is true that, so far as I know, no modern biologist regards, as did the ancient Greek, love as the "center of the whirl," the question of what brings the parts together is less important than the supposition that originally they were independent—some in one quarter, some from another. An organizer or a psychoid, for example, may appear to some more scientific than "love" as an agent for doing the trick. But really if one's curiosity goads him to inquire about the intrinsic nature and the origin of the agent, I fail to see much if any advantage of these modern over the ancient explanations.

[2] Charles M. Bakewell, "Source Book in Ancient Philosophy," p. 45, 1907.

While it has sufficed for our discussion thus far to speak of the head and the limbs as the correlated parts, we must now be more specific, more analytic. No one will hesitate as to what some of the most important specifications must be. The muscular and neural parts of the structure involved must certainly be noticed. So far as concerns the head the brain is a crucial sub-part. Even "brain" is too general if one is eager to understand the ways of life of birds or any other vertebrate animals; the cerebral part of the brain must come into special reckoning. I am here assuming that along with my reader's familiarity with the wonderful activities of birds in breeding, nest building, incubating, caring for the young; also with their abilities in meeting their necessities for food and other things, there is connected some knowledge of the dependence of these activities on the anatomical and biopsychical nature of individual birds; and that in this nature the brain is of foremost importance.

The knowledge we now possess of the dependence of avian ways of life on the use birds make of their body parts acting cooperatively and our knowledge of the racial history of birds and their parts lead us to expect that many of the parts would be a sort of anatomical record of that history. Considering the great dominance of locomotion in their activities, we ought to expect that the record suggested would be especially distinct in the brain and the fore limbs, these being the parts most directly involved in locomotion.

Recurring to the other member, humans, of our comparative duet, we are justified by all the best established knowl-

edge of living things in presuming that the general principles relied upon in interpreting birds will hold for interpreting humans. These principles are: The unity of ground plan of birds and humans, making them namable as vertebrates; the dependence of each individual existence and way of life on its ability to use its parts in cooperative action so as to assure its own existence and enable it to produce other individuals like itself; the existence of racial or ancestral lines composed of myriads of individuals, the existence of each of which must have depended on its parts in like fashion with the dependence of its living descendants; and finally the modifiability by natural causes of individuals to produce new *kinds* of individuals.

Let us put now a typical bird (one of my woodpeckers, for example) and a typical human (my humble self, for example) alongside each other to make the comparison unqualifiedly concrete. The woodpecker's wings and my arms and hands may receive first attention, since "way of life" of each of us is foremost in interest. Nothing either of us can do with our heads can be so momentarily striking as the bird's winged dart into the air after flying insects or in play; and the arm-swinging of my morning gymnastics. But no spectator of our performances could be oblivious of the fact that our brains are concerned in what he may see us doing, despite the exceeding inconspicuousness of brain action. How unfortunate that the activities that go on in the brain and nerves of an acorn-harvesting-and-storing California woodpecker, and an acorn-harvesting-and-storing California Indian woman, can not be thrown on the screen side-by-side with the activities of wings and arms-hands of the performers! We must depend on the neurologists and physiologists for the brain-nerve portion of this comparison. By dint of great labors they have made much knowledge available for our enterprise. Note the results as applied to these two performers: While the woodpecker can beat the Indian all hollow at gathering acorns from the trees, the Indian can beat the woodpecker still more at storing them and utilizing them for food.

The reason for this is perfectly obvious so far as the fore limbs are concerned: The birds can reach the acorns with the greatest ease even on the tops of the tallest oaks, or from oaks in the most inaccessible places—for ground travel. But they must make a separate trip, forth-and-back, for every nut, their fore limbs being entirely excluded from direct participation in the business. No collecting basket or bag here—only the mouth for picking and carrying, even this being of only one nut capacity!

And as to storing—well, that these woodpeckers do a remarkable job is widely recognized, but it is remarkable only as a *bird* job—not as a *human* job. For even the Indians often construct a storage place for the nuts that, simple as it is, requires more varied and complex activity and is, on the whole, much more efficacious than the sort of storage place made by the woodpeckers. Furthermore, the Indians subject the acorns to various quite elaborate processes in preparing them for eating, of which the woodpeckers do nothing whatever and about which they know nothing.

In connection with the fore-limbs aspect of the comparison, it is obvious that an extensive set of activities involved in the Indian way of life with respect to the nutritial function is performed by means of these limbs, modified into arms-hands, that is, organs for grasping and holding. This set of activities is wholly absent from the woodpecker's way of life, due to the fact that these members have been modified into wings, organs for a unique and exceedingly efficient way of travel.

Considering the difference in the avian and human brains that should correspond (according to the principle of correlation of parts) with the different uses the two

kinds of creatures make of their fore limbs, let us first notice what the comparative anatomy of the two brains shows. It is a commonplace of the anatomy and embryology of vertebrates that the brain presents a ground plan quite as clearly recognizable as is the ground plan of the backbone, the eyes or of the blood-circulating system.

Embryology makes clear the beginning of the brain by modification of the front end of what becomes the spinal cord into three enlargements known as primary vesicles. By extensive growth and modification of these vesicles all the variously sized and shaped brains of the many classes and orders of vertebrates come into existence. Although the modifications in each of these vesicles are extensive they are much greater in the first, counting from before backward, than in the other two. While the parts of the adult brain derived from the second and third vesicles are present in all vertebrates, from fishes to humans, certain parts derived from the first vesicle are almost wholly lacking in fishes as less evolved members of the branch; while other parts derived from this vesicle are present in great size and elaboration in the more evolved members.

On the basis of these anatomical and developmental facts investigators have adopted the terms "old brain" and "new brain." These terms are expressive and quite justified, provided one never forgets that they refer to two parts of one and the same brain and not to two distinct brains.

What this nomenclature means is that while all vertebrates from the evolutionally oldest (fishes) to the evolutionally youngest (humans) possess the oldest portion of the brain, only the evolutionally youngest possess the new brain in its largest, most highly elaborated form. The cerebrum, which constitutes by far the chief mass of the human brain, hardly exists in fishes. If even its beginning is present here it is so small and indistinct as to be hardly recognizable.

Now for the bearing of all this on the comparison of the human and the avian brains: While in both the cerebrum is unmistakenly present, in the human brain the cerebrum, with the cerebral cortex, is enormously larger in proportion to the entire brain than it is in the avian brain. I know of no serious effort to determine the quantitative relation between old brain and new in either men or birds. Mere inspectional estimates made by several persons on the basis of published figures agree on about twenty (old) to eighty (new) for the human, and ninety (old) to ten (new) for the avian. From all that is now known about the neuro-muscular system (anatomical) and the sensory-motor system (functional) it would seem beyond question that the striking differences between human and avian brains are correlated with the most striking differences between the two groups in their ways of life. No doubt many other body parts are involved in the correlation, but these parts must be preeminent in the involvement. Accordingly, we may say the great dominance of new brain over old brain in humans may be viewed as a sort of anatomical record of the great dominance of the activities humans perform by means of their fore limbs in operating on the external world; and of the highly complex activities they perform by means of their mouths and other vocal organs for communicating with the animate world, especially the human portion of it. Contrariwise, the great dominance of old brain over new brain in birds may be viewed as such a record of the great dominance of the activities birds perform by their fore limbs in moving from place to place and of the relatively simple activities they perform by means of their mouths and vocal organs for purposes of communication.

It will be remembered that our comparative illustration called attention to the great advantage (on the whole) the Indians have over the woodpeckers in utilizing acorns for food; and that in the

main this advantage is in the fact that the Indian's hands are utilizable for the purpose, while the bird's wings are not at all so utilizable—*directly*. No reference was then made to the fact that the structural-functional conditions on the basis of which hands are utilizable in the acorn business makes them utilizable in hundreds of other businesses. It is doubtful if any single item in the entire way of life of animals has been a more potent determiner of a group's status in the whole animal world than the utilizability of the human fore limbs, especially the hands, for hundreds, even thousands of different purposes. Recur again to the Indian woman in the acorn business, as the first in a comparative series. While she is manipulating (note the relation of the word to *manus*, the hand) the acorns, another woman of some other tribe may be weaving baskets, while still another is weaving rugs, another decorating a papoose carrier with beads, and so on. Simultaneously an Indian man somewhere may be chipping a piece of flint for an arrowhead; another somewhere else may be pulling his bow string to speed his arrow at his prospective victim; another may be fashioning a bit of copper or silver into a finger ring, while yet another may be making a flute from a long bone of some large bird.

No one can follow such a lead, taking Charles Darwin's attitude toward natural history and the origin of man, and fail to enter finally the whole world of industrial and fine arts.

Then there is the other aspect of the same great scene—the aspect that exists in virtue of the utilization of the human mouth and vocal organs in producing language. That speaking as men do speak is no less certainly dependent on neuro-muscular activity than is weaving, writing and piano playing, no informed modern doubts. So it comes to pass that the way of life of the human species taken in its complete reality shows us still another unbroken series typified by the Indian mother's simple speaking to her infant, through the measurably complex tribal chant, on to the oratory of a Demosthenes or a Pitt; or to the opera singing of a Schumann-Heink.

The scene is not yet complete even in outline, for it does not contain a hint of the remarkable interlocking of the arms-hands series and the vocal organs series. Starting with the Indians again, notice some specially gifted individual manipulating a crudely fashioned paint brush to mark some rock with characters that stand for or symbolize objects and acts long and well known and talked about by him and his kindred. The lead thus presented brings us finally to such productions as Plato's "Republic," Mommsen's "Roman History" or Shakespeare's "Hamlet." Here is presented also a way of life, a mode of activity, that illustrates a functional correlation of parts in the case of head-and-hands that is peculiarly significant. The reference is to mathematics. We read: "Mathematics is a game played according to certain simple rules with meaningless marks on paper."[4] This definition is, according to Bell, by David Hilbert, said to be regarded as the foremost living mathematician.

While such a conception may seem to some persons a "drastic deflation of mathematical truth" (Bell), to a naturalist it appears to bring the activities involved into line with the conception of natural history as one of man's most highly specialized and important ways of life. Would any cultivator of "pure mathematics" contend that the reasoning involved might be carried even theoretically by the mind without marks of any sort or anywhere either on paper or on the tablets of his imagination? Hand activity seems to be as indispensable to mathematics as is brain and mind activity; and the higher, more involved and recondite the reasoning involved, *i.e.*, the more elaborate the equations or other

[4] E. T. Bell, "The Queen of the Sciences," p. 21, 1931.

language employed, the more indispensable the hand activities, for the more difficult it becomes to carry the language in the mind exclusively. This probably explains the fact that a professedly idealistic philosopher or "thinker" banks more on the pure reason theory of mathematics than does a working mathematician himself.

Once the idea of a living animal organism is seen to involve the coordinate idea of a whole-with-its-correlated-parts, adapted to its environment, it becomes clear that all manual activity, including every phase of scientific research, expended upon any part of the environment, is basically and organically in behalf of the welfare of the acting being and its kind. All such activity is adaptive or mal-adaptive. It affects in some way, either for good, bad or indifferent, the acting individual or its race or both.

Pure science, pure art, pure thought, pure anything in the sense of being no part of the way of life of living individuals seems to be pure fiction; that is to say, is objectively non-existent, no less for humans than for birds or any other species. The deepest responses to stimuli, impulses and acts put forth by every animal being is really for well-being—well-being of the individual *qua* individual and *qua* race or kind or species.

Returning to our concrete examples—California woodpeckers, California Indians, and my own self—the question arises: How is it that I can utilize my head and fore limbs toward knowing and understanding the others of the trio so much more extensively than either of them can or at least do?

Taking the woodpeckers first, I approach the general question through a particular question: How is it that I could show the birds how to act for their own good in the acorn business much more effectively than they frequently do act, despite the fact that their good and not mine is concerned? For instance, I could easily tell—even show them—that there is no necessity to store nuts (as they quite often do) in places where they can not possibly get them, however much they may need them, for food. Or I could easily inform the birds of the risks they run from the orchardist's shotgun, in raiding his almond orchard. This risk is the more deplorable when taken, as it often is, with an abundance of acorns easily accessible. The truth is I am really disturbed over this conduct of theirs. I would go to considerable trouble to warn the birds if they could understand me and would heed my warning.

A noteworthy point about these and other kinds of unfortunate or maladaptive performances by the birds is that their inability to handle the nuts with their wings is not involved. So far as their "beaking" (instead of "handling") the nuts is concerned they could do the right or safe thing as well as the wrong and dangerous thing.

The long and short of the matter is that the beggarly development of the new brain proportionately to the rest of the brain in woodpeckers as in all other birds is a dreadful handicap to them when situations are met that call for choice and decision as between particular acts and ends. Any hole in wood about the size of an acorn seems to look to these woodpeckers like a proper receptacle for a nut, no question being raised as to where the hole may lead from the standpoint of the recovery of the nut at some future time. The brain-mind endowment of the birds is sufficient to make them aware that acorns will contribute to their later as well as to their present state of existence. But it is not sufficient to make them aware of many of the conditions upon which the later availability of the nuts depends. Turn now to the Indians.

So far as recognizing the sustentative quality of the acorns is concerned, these humans would not appear to differ greatly in brain-mind endowment, just as they do not differ in digestive and assimilative endowment, from the woodpeckers.

Both obviously trust implicitly, on the strength of much experience, in the sustentative quality of the nuts. Undoubtedly the fact that the birds eat the nuts with no sort of culinary preparation, while the Indians put them through quite elaborate preparation, has some mental influence. But that the vital nutritive and biochemical significance is fundamentally alike for both, is undoubted. When it comes to the conditions upon which the later availability of the nuts depends, the difference between the two groups is enormous—as shown, for one thing, by what the Indians do in storing the nuts with reference to assuring their later availability, and to preparing them as food. In the first place they would never deliberately put their acorns in places entirely inaccessible to them—as we have noted the birds do rather often.

Then the bins, or granaries constructed of sticks, brush, grass, etc., by some of the Indian tribes for storing, simple and crude though they are, are truly designed to keep the stores dry and in some measure safe from predatory animals.

All this involves correlated brain-hand activity of no mean order. The equipment required for much of the action involved is such as to make it available for many other kinds of action to many other ends.

We may now turn to the previous question about my humble self and my ability to instruct the birds how to improve their work to their advantage, even though my work and my advantage were not involved—at least in any direct way. Again how is it that I could instruct the Indians on ways of improving their work of harvesting and storing acorns and of using them for food even though my own food needs were not at all involved? How is it that I cogitate for hours over this general problem and try hard and long to write about it in a fashion that will help to clarify my own cogitation and that of others should they be interested in such matters and happen to read what I write?

The question about helping the Indians in the various aspects of their acorn business can be partially answered with ease. Whatever is at my command but not at theirs through the industrial arts, invention, scientific discovery, and so on, is unquestionably first and foremost of head-and-hand activities that were at their command originally but have since developed in our civilization far beyond their original status. Whatever improved methods of harvesting, building, dish-making, grinding, cooking and food-serving I and my fellow immigrants could teach the native residents, these were unquestionably potential in their own simple and crude harvesting, storage-place constructing, basket-weaving, mortar-making, water-using, fire-starting-and using, spoon-making and feeding. Such unquestionable potentiality is proved by the fact that once shown how to do these things, modernly, the Indians do them sometimes quite as well, sometimes not quite as well, but sometimes rather better than we highly cultured newcomers can do them.

In other words, the question that now confronts me is: How is it that I am so vastly better off in my way of life as to food than are either the California woodpeckers or the California Indians?

As for the woodpeckers the answer is, as this whole presentation makes clear, because my sensori-motor equipment, represented especially by my brain-hands combination, is so vastly better fitted than is that of the birds for dealing with the general food problem.

But when it comes to the portions of the question about the Indians not included in the easy answer as above indicated, serious difficulties loom up. These may be more sharply stated as follows: How is it that although my sensori-motor equipment, also represented especially by my brain-hands combination, is little if any superior to that possessed by the Indians, nevertheless I (with my cultured group) actually do surpass the

Indians enormously in dealing with the food problem.

The size of the debt we humans to-day owe our ancestors in the earliest stages of human evolution is measurable only with reference to our valuation of our own lives at our present evolutional level, physical and cultural. For included in that debt is not merely the basic stages and elements of our culture, but the basic stages and elements of our sensori-motor equipment for performing the activities on which our cultural evolution depends.

Not many aspects of the problem of mankind are found to surpass in importance and difficulty that here indicated, once serious effort is made to deal with the complete reality of *Homo sapiens* in accordance with the Darwinian principle of descent with modification (evolution). As might be expected, anthropologists seem to have felt the problem with special concreteness. One of them has expressed it in striking epigrammatic fashion: . . . "even now nobody knows whether man's brain is so large because he is so intelligent or whether he is so intelligent because his brain is so large."[5]

One cardinal aim of this article is to show that we moderns are not, or need not be, so much in the dark on this matter as such utterances indicate. If "intelligent" in such a context be viewed as a descriptive term for a quality of an individual, which quality depends on the functioning of its parts, then such an antithesis as that implied by the epigram does not exist. The sentence is really meaningless. Neither in biotic metabolism nor logic can an organ or its function exist, strictly speaking, the one *before* the other.

That such a view of "intelligent" is implied by this entire discussion of mine can, I trust, not be missed by any reader. According to my view for an individual animal, a woodpecker, an Indian or myself, for example, to be intelligent is to use its entire sensori-motor equipment (of which the brain-hand combination is of first importance) so as to secure its continued existence and that in the highest measure possible for the individual itself and as a member of its species and, generally, for its particular group.

By approaching the whole vast subject from the side of natural history as Mr. Darwin conceived natural history, and from the view-point of the organismal conception as it is being developed in present-day zoology especially, it is possible, I believe, to go a long way toward solving the puzzle.

On the basis of the fundamental truth contained in the maxim "self-preservation is the first law of life" it is now recognizable that awareness by an individual animal of the advantage of avoiding particular acts that might result in its own death or serious injury, is the initial step toward modifying the kind of selection called natural by Darwin into what is familiar to almost everybody as conscious, rational or (in Darwinian terminology) artificial selection. Artificial selection may be called natural selection raised to the nth degree of effectiveness.

Another expression for much the same thing is possible by utilizing the phrase trial and error, especially familiar to zoologists: Artificial selection is nature's method of increasing success to a maximum and reducing error to a minimum, in individual activity.

In these few brazenly dogmatic sentences I have tried to cram the essence of much that is contained in the two books mentioned on the first page of this article.

Nearly central to the book entitled "Nature" is a discussion of something like 70,000 words of the problem of getting and using natural knowledge (epistemology of traditional philosophy) approached from the side of natural history and the organismal conception. The undertaking follows the lead of Mr. Darwin in his approach to the subject of the moral sense or conscience, from the

[5] E. A. Hooton, "Up from the Ape," p. 141, 1935.

side of natural history. Still more fundamentally, it follows Darwin's lead in conceiving man as natural in every quality of his being in the same sense that he is natural in any other quality of his being.

This insight by Darwin, although only partial and dim in some of its aspects, marks him as indeed an "intellectual colossus"[5] and places him among the very foremost persons of all time who have contributed to the carrying out of the Delphic Oracle's command, Know thyself. Whether "anthropology is the child of Darwin," as viewed by some anthropologists,[6] I venture no opinion, not being an anthropologist myself. I do not hesitate, however, to say as a zoologist that until man could be viewed as natural in the same sense that every other zoological species is natural, no trustworthy general knowledge, much less understanding and theory, of man was possible.

So long as men (the males of the species, I mean; what I am about to say applies less to the females) consider themselves as *not* natural, *i.e.*, as supernatural, in certain of their qualities while natural in other qualities; or consider that certain individuals among them are wholly supernatural, they are in the same boat with those "savages" and culturally backward peoples (the Hindus, for example) who regard certain sub-human animals as sacred and proper objects of worships. Here is another of the almost endlessly varied outcrops of what seems to have been one of the earliest efforts of the human species at theorizing about its own nature, namely, the effort that has produced the familiar doctrine of "mind or soul *versus* body."

[6] R. R. Marett, "Anthropology," p. 8.

One of the foremost results of the epistemological enterprise referred to is highly remedial for this tragically disintegrative conception of humans and other kinds of animals. This result depends largely on recognizing that all the most definitive qualities of humans—those powers and activities of theirs named thinking, reasoning and understanding, are inseparable (as far as all trustworthy evidence is concerned) from certain qualities manifested by all bodies known as living from bacteria to oaks and redwoods, and from amoebae to woodpeckers and my precious self.

Here, then, is what the "mutually interpretative relation between human and avian natural history" comes to as exemplified by the couplet of myself and the California woodpeckers: My wonderful superiority over them in anatomical-physiological equipment for acting for the welfare, on the whole, of myself and of my kind makes me also an illustration of the classificatory view expressed by Mr. Darwin that the quality by which the species, *Homo sapiens*, is most distinctly differentiated from all other animal species is the "moral sense or conscience."

However, this wonderful anatomical-physiological superiority of mine for acting adaptively entitles me to no such ranking in the moral realm unless I use the equipment in accordance with its own nature, namely, that of acting for my own welfare and that of my kind to the fullest extent possible in every situation in which I act consciously at all.

Exceedingly greater personal responsibility for my own acts as compared with that of any bird for its acts may be compendiumized as the sum and substance of this essay.

THE FARADAY-WHEWELL CORRESPONDENCE CONCERNING ELECTRO-CHEMICAL TERMS

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THE terms *electrode, anode, cathode, anion, cation, electrolyte,* etc., have now entered on their second century of usefulness. They have met the test of time and constitute a permanent monument to the good judgment and acumen of their genitors. To whom is the world really indebted for these excellent words, which even laymen are finding indispensable? Should the entire credit go to Faraday, who was the first to use these terms, some partly his own invention, others coined at his request? A large share of the honor indubitably belongs to Whewell, the competent counselor to whom Faraday appealed for advice and suggestions when he found it impossible to expound his electrochemical researches in the existing vocabulary.

William Whewell, D.D. (1794–1866), one of the most brilliant men that Cambridge has produced, spent his entire career in the service of this university.[1] As fellow, professor (mineralogy, 1828–33; moral philosophy, 1838–55) and master of Trinity College (1841–66) he exerted a decided influence, both by example and legislation, in the strengthening of science teaching. Trained initially as a mathematician, his mind was too versatile to be kept within the bounds of a single field, and he shifted part of his energy to science, especially physics, but in science he was an able critic rather than an originator. In middle life he turned his attention particularly to philosophy and to history of science, "not that I do not still love science, but in it I have done all that I can." He is now best known for his elaborate historical reviews[2] of the processes of generalization.

In these volumes he exhibited a wideness of knowledge that at the time placed him in a class almost by himself. John Herschell was probably not far from the truth in his eulogy: "A more wonderful variety and amount of knowledge in almost every department of human inquiry was perhaps never in the same interval of time accumulated by any man." The quip, "science is his forte and omniscience is his foible," was applauded by those who thought that he had spread his talents too thin, but Lyell saw with a clearer eye when (1837) he wrote to Whewell:

> There was a time when I used to regret that you had not concentrated your powers on some one department of physical science and become a giant in that, or at least that you had been satisfied with some two or three of the Arts and Sciences, but I have for some years come round to the belief that you have been exercising the

[1] For biographical material see I. Todhunter, "William Whewell, an Account of his Writings, with Selections from his Literary and Scientific Correspondence," 1876; Mrs. Stair Douglas, "The Life and Selections from the Correspondence of William Whewell," 1881; L. Stephen, "Dictionary of National Biography," Vol. 60, p. 454, 1899.

[2] (a) "The History of the Inductive Sciences from the Earliest to the Present Time." 3 vols., 1837. New edition, revised and continued, 1847; (b) "The Philosophy of the Inductive Sciences founded upon their History," 2 vols., 1840. A new edition, with corrections and additions, 1847.

calling for which Nature intended you, and for which she gave you strength and genius, and that you have given a greater impulse to the advancement of science among us by being a Universalist, and by mastering so much of Chemistry, Mineralogy, Astronomy, Geology, and other branches, than you would have done if restricted to the perfecting of any one alone.

During his student days, Whewell showed marked ability in Latin and Greek and in his early years planned to devote considerable attention to linguistics. Even after his mathematical and scientific labors checked this youthful intention, he continued his deep interest in etymological studies and speculations. He wrote extensively on the language of science.[3] He was acquainted with many of the scientific leaders of the day, and to them he made no secret of his passion for correct usage of classic roots in the construction of new scientific terms. He freely offered his services as consultant and critic in such matters, and his expert knowledge was used by some of the most eminent of his scientific contemporaries. Bell, Lubbock, Lyell, Murchison, Owen, adopted names that had been suggested by him or that had been submitted for his appraisal.

The chief beneficiary of Whewell's terminological cooperation was Faraday. Elected to the Royal Society in 1824, he there came to know Whewell (elected in 1820), and as his own formal schooling had been so scanty, ending when he was thirteen, he doubtless was impressed by the breadth of the culture possessed by the Cambridge savant. On the other side, Whewell could not but admire Faraday's scientific powers, and a friendship was established between these two whose basic training had been so dissimilar.

Electricity was always of great interest to Faraday, and he worked on it intermittently even during that period, 1816–1831, which saw him develop into a chemical investigator of the first rank. He discovered electromagnetic induction in August, 1831. This was the turning point in his career, and now began that series of celebrated studies that were recorded in the successive series of his "Experimental Researches in Electricity and Magnetism." Novel results required new terms for their exposition, and as early as November 29, 1831, in a letter[4] to Richard Phillips, the chemist, Faraday tells of a new term: "*The Electrotonic State.* What do you think of that? Am I not a bold man, ignorant as I am to coin words but I have consulted the scholars." When he put this term into print, he did not disclose his consultants: "I have after advising with several learned friends ventured to designate it as the *electrotonic* state."

This first instance of the introduction of a new term by Faraday is characterized by two features that accompany all the subsequent examples: (1) He did not venture to proceed independently in the coining of words; (2) he did not publicly name the philological experts from whom he sought counsel and suggestions.

Although Whewell probably was not one of these "learned friends," the two were by this time on an easy footing with each other and Faraday knew of Whewell's expertness in such matters. Only a few months before, on February 21, 1831, he had written to Whewell concerning the use of scientific language:

I cannot help thinking it is a most unfortunate thing that men who as experimentalists and philosophers are the most fitted to advance the general cause of science and knowledge should by the promulgation of their own theoretical views under the form of nomenclative notation or scale actually retard its progress. It would not be of so much consequence if it was only

[3] See, for example, his "Aphorisms concerning the Language of Science" in his "Philosophy," vol. 2, 1847, p. 479.

[4] S. P. Thompson, "Michael Faraday, His Life and Work," p. 116. 1898.

theory and hypothesis which they thus treated, but they put facts or the current coin of science into the same limited circulation when they describe them in such a way that the initiate only can read them.[5]

Faraday's researches soon led him into the long-standing problem as to whether the electricity derived from different sources is identical. Chemical action was an obvious test, and this line of attack took him directly into a study of conduction of solutions and fused compounds, its mechanism, its constant association with decomposition, the liberation of the decomposition products at the poles rather than in the body of the conducting liquid, the relation of the amount of chemical action and the quantity of electricity passed, etc. His success in the solving of these problems is well known, but only cursory attention has been given to his equal success in inspiring the construction of a satisfactory terminology when he found no words in the language with which to clearly express his thoughts and findings.

Chemical decomposition accompanying electrical conduction was no new subject to one who had been so closely associated with Davy, but Faraday soon saw that the prevailing theory was untenable.

It was generally assumed that the wires by which the current entered and left the decomposing substance acted like positively and negatively charged conductors, and by their electrical attraction tore the reluctant atoms from the compound molecule. Faraday saw that this hypothesis would not work. He knew that by suitable arrangements the strongest chemical compounds could be broken up by the feeblest currents. It would follow, therefore, on the old hypothesis that the feeblest current was stronger than a powerful chemical attraction. This seemed to Faraday very improbable. Before pushing his experiments further Faraday felt the necessity of clearing the ground of the relics of the older theory by giving new names to the various phenomena. He appreciated fully the tyranny that mere names can wield over the human intellect, and determined to free at least this branch of science from their baleful influence by a nomenclature which should imply nothing beyond what had been experimentally confirmed.[6]

The word *pole*, from its association with the magnet, was barnacled with meanings and implications opposed to what he believed: "the determining force is *not* at the poles but *within* the body," and so he replaced this misleading term by one more consistent with this belief that: "the poles are merely the surfaces or doors by which the electricity enters into or passes out of the substance suffering decomposition." *Electrode* (Gr. electron + *hodos* = way) appears for the first time on December 17, 1833. The Diary[7] (§ 1173) for that day records that when he passed a current through "fuzed Proto chloride of Tin" he observed that "Deuto chloride of tin passed off from the P. Electrode and Metallic tin was rendered at the N. Electrode." Later that day (§ 1175) he wrote: "Hence 1.76 of tin had been electrochemically evolved at the *exode* and of course a corresponding proportion of chlorine at the *cisode* . . ."[8]

He also required a word to express "those bodies which can pass to the electrodes." The entry for December 19

[5] The Council of Trinity College has generously given leave to publish here for the first time extracts from the Faraday-Whewell correspondence. Other letters that have already appeared in print are reprinted here in order to complete the picture.

[6] J. A. Crowther, "The Life and Discoveries of Michael Faraday," p. 39 *ff*. 1918.

[7] "Faraday's Diary. Being the various Philosophical Notes of Experimental Investigation made by Michael Faraday during the years 1820–1862." Bell, London, 7 vols., 1932–36. Volume II, 1932, covers the period from August 25, 1832 to February 29, 1936, §§ 1–3025.

[8] *Cisode* is given in §§ 1175, 1195, 1325, 1591, 1738, but nowhere else. The Faraday-Whewell letters contain in its place *eisode*. Faraday's "e" and "e" are easily mistaken for one another. Thomas Martin, editor of the Diary, after a special examination of this Faraday manuscript, insists that Faraday wrote and intended to write *cisode*.

states: "When a body of known composition is decomposed directly by the Electric current, may conclude that its proximate principles are *Electrobeids.*" This term (probably derived from the Greek baino = I go) had obvious disadvantages and was soon replaced by *zetode,* which in turn gave way to *ion.*

These, together with other *mots d'occasion,* were given a public trial on January 23, 1834, when Faraday read before the Royal Society the first part of his now famous paper,[9] in which he summarized all his previous work on electrochemistry. He began:

> The theory which I believe to be a true expression of the facts of electrochemical decomposition —is so much at variance with those previously advanced, that I find the greatest difficulty in stating results, as I think, correctly, whilst limited to the use of terms which are current with a certain accepted meaning—To avoid, therefore, confusion and circumlocution, and for the sake of greater precision of expression than I can otherwise obtain, I have deliberately considered the subject with two friends, and with their assistance and concurrence in framing them, I purpose henceforward using certain other terms, which I will now define.

Then follow definitions and derivations of *electrode, anode, cathode, electrolyte, electrolyzed, anion, cation,* . . .

> These terms being once well defined, will, I hope, in their use enable me to avoid much periphrasis and ambiguity of expression. I do not mean to press them into service more frequently than will be required, for I am fully aware that names are one thing and science another.

No one, and least of all Faraday, has given a clear history of the genesis of this terminology. His statement, "I have deliberately considered the subject with two friends," is his only public acknowledgment of indebtedness; he nowhere tells who his advisers were.[10]

The confusion and uncertainty arises from the following sequence of events. Faraday, in his paper of January 23, presented a set of new terms, which probably had been concocted in somewhat of a rush. After due reflection and possibly after consultation, it became apparent that some of these terms did not meet the requirements, and wishing further expert advice and fresh intelligence he decided to place his problem before the person generally recognized as the best authority on scientific language. Whewell, who had heard the paper, gladly gave the matter the attention it deserved, and when in May, the proof sheets came to Faraday for correction, he substituted Whewell's proposals for some of the terms he had used in January. Consequently, *electrobeid, exode, eisode* (or *cisode*) and probably others, never appeared in the published paper. The only printed evidence of the alterations in the terminology was the footnote, "Since this paper was read, I have changed some of the terms which were first proposed that I might employ only such as were at the same time simple in their nature, clear in their reference, and free from hypothesis."[11]

The electrochemical terminology for the most part was evolved during the period between the reading and publica-

[9] Philosophical Transactions of the Royal Society of London. For the year 1834, Part I: Experimental Researches in Electricity. Seventh Series. By Michael Faraday. Received January 9, Read January 23, February 6 and 13, 1834, p. 77, On Electrochemical Decomposition, continued IV.

[10] The letters mention Mr. Willis and Dr. Nichols. Though Faraday's spelling of names can not be trusted, (*e.g.*, Nicol, the inventor of the prism, appears in the Diary also as Nicholl, Nichol) no men of science of these or similar names seem to fit the rôle of advisers in his introduction of new terms.

[11] The authorities of the Royal Society and of the Royal Institution, at the writers' request, searched their archives for the original manuscript and the corrected proof sheets. No trace of either was found, and Faraday probably destroyed the originals after he had made the substitutions and alterations. The terms he discarded can now only be inferred from the Diary and the letters.

tion of the paper, a fact that hitherto has either been unknown or disregarded, with the result that Whewell has never been given adequate credit for the predominant part he played in the coinage of these new terms.[12]

He not only made suggestions but also argued Faraday into accepting terms whose excellence has now been amply demonstrated. Nowhere has Whewell put forth any claims for any part of the honor; on the contrary, he sedulously fostered the belief that Faraday alone was responsible for these terms.[13]

About 65 items of the Faraday-Whewell correspondence are in the library of Trinity College, Cambridge, including letters dealing with the genesis of the electrochemical terminology. Some of these have been published, but others, equally important to this present discussion, have never appeared in print. The letters tell the story and need no comment. Faraday's punctuation is almost nil, and there is little consistency in his use of capitals.

I

Faraday to Whewell

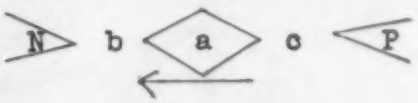
Royal Institution
24th April, 1834

My dear Sir

I am in a trouble which when it occurs at Cambridge is I understand referred by everybody in the University to you for removal and I am encouraged by the remembrance of your kindness and on Mr. Willis' suggestion to apply to you also But I should tell you how I stand in the matter.

I wanted some new names to express my facts in Electrical science without involving more theory than I could help & applied to a friend Dr. Nicholl who has given me some that I intend to adopt for instance a body decomposable by the passage of the electric current I call an "*electrolyte*" and instead of saying that water is *electrochemically decomposed* I say it is "*electrolysed*" The intensity above which a body is decomposed beneath which it conducts without decomposition I call the "Electrolytic intensity" &c &c. What have been called the poles of the battery I call the *electrodes* They are not merely surfaces of metal but even of *water* and *air* to which the term poles could hardly apply without receiving a new sense. *Electrolytes* must consist of two parts which during *electrolysation* are determined the one in one direction the other in the other toward the electrodes or poles where they are evolved These evolved substances I call *zetodes* which are therefore the direct constitutents of electrolites. (*sic*)

All these terms I am satisfied with but not with two others which I have used thus far. It is essential to me to have the power of referring to the two surfaces of a decomposable body by which the current enters into and passes out of it without at the same time referring to the electrodes. Thus let *a* be a decomposable body & P & N the pos & neg poles which may or may



not be in contact with *a* at the points *b.c* and shall yet transmit the electricity which passes through *a*

Admitting the usual mode of expression and talking of a current of Electricity proceeding from the positive pole P through *a* to the negative pole N my friend suggests and I have used the terms *eisode* for c and *exode* for b, the points where the *Zetodes* are rendered and a zetode going to c I have called a *seteisode* and another going to b a *setexode*

But the idea of a current especially of *one* current is a very clumsy and hypothetical view of the state of Electrical forces under the circumstances The idea of *two* currents seems to me more suspicious and I have little doubt that the present view of electric currents and the notions by which we try to conceive of them will soon pass away and I want therefore names by which I can refer to *c* & *b* without involving any theory of the nature of electricity. In searching for a reference on which to found these I can think of nothing but the globe as a magnetic body If we admit the magnetism of the sphere as due to electric currents running in lines of latitude their course must be according to our present modes of expression from East to West and if a portion of water under decomposition by an electric current be placed so that

[12] See, for instance, J. Tyndall, "Faraday as a Discoverer," 1868, p. 54; J. Gladstone, "Michael Faraday," n.d., p. 181; H. Hartley, *Chem. News*, 144: 410, 1932; Thompson, *op. cit.*, p. 143.

[13] "History," 1847. Vol. 3, p. 184; *idem*, "Philosophy," 1847. Vol. 1, p. 52; Vol. 2, pp. 537, 547.

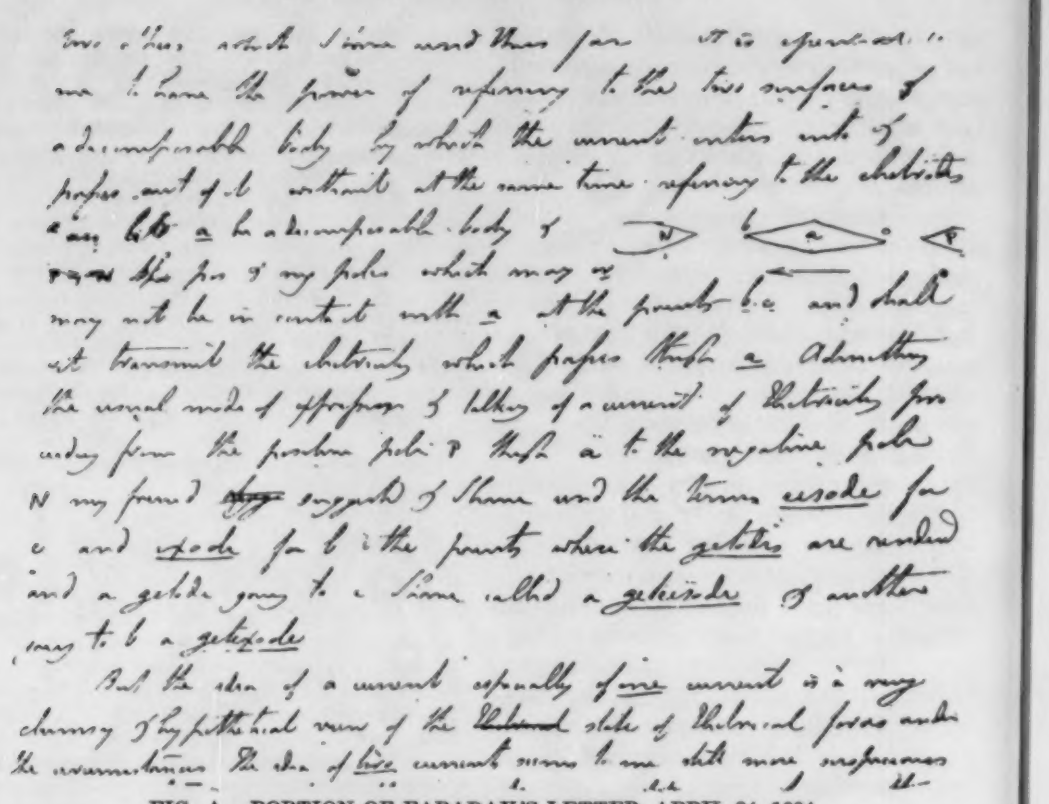


FIG. A. PORTION OF FARADAY'S LETTER, APRIL 24, 1834.
NOTE HIS ORIGINAL TERMS: EISODE, EXODE, ZETEISODE, ZETEXODE.

the current through it be parallel to that circulating round the earth then the oxygen will be rendered toward the east as at *c* in the figure and the hydrogen toward the west as at *b* in the figure I think therefore that if I were to call c the *east-ode* and *b* the *west-ode* I should express these points by reference to a standard which whatever changes take place in our theories or knowledge of electricity will still have the same relation But Eastode or Westode or oriode and occiode are names which a scholar would not suffer I understand for a moment and *anatalode* and *dysiode* have been offered to me instead.

Now you can help me out to two good names not depending upon the idea of a current in *one direction only* or upon positive or negative and to which I may add the prefixes zet or zeto so as to express the class to which any particular *setode* may belong.

I am making very free with you if you feel inclined to help me I shall be very much obliged and if not may (*sic*) no ceremony in saying that you cannot assist me.

II

Whewell to Faraday[14]

Trinity College, Cambridge.
April 25, 1834.

My Dear Sir,

I was glad on several accounts to receive your letter. I had the pleasure of being present at the R. S. at the reading of your paper, in which you introduced some of the terms which you mention, and I was rejoiced to hear them, for I saw, or thought I saw, that these novelties had been forced upon you by the novelty of extent and the new relations of your views. In cases where such causes operate, new terms inevitably arise, and it is very fortunate when those, upon whom the introduction of these devolves, look forward as carefully as you do to the general bearing and future prospects of the subject; and it is an additional advantage when they humour philologists so far as to avoid gross incongruities of language. I was well satisfied with most of the terms that you mention; and shall be glad and gratified to assist in freeing them from

[14] I. Todhunter, *op. cit.*, Vol. 2, p. 175.

false assumptions and implications, as well as from philological monstrosities.

I have considered the two terms you want to substitute for *eisode* and *exode*, and upon the whole I am disposed to recommend instead of them *anode* and *cathode*. These words may signify *eastern* and *western* way, just as well as the longer compounds which you mention, which derive their meaning from words implying rising and setting, notions which anode and cathode imply more simply. But I will add that, as your object appears to me to be to indicate opposition

and it is very fortunate when the [illegible] is the introduction of those denotes [illegible] forwards as carefully, as you do the general bearing and future prospects of the subject; and it is an additional [illegible] when they human philologists so far as to avoid [illegible] of language. I was very satisfied with both of the terms that you mention; and shall be glad and gratified to assist in freeing them from false assumptions and implications, as well as from philological monstrosities.

I have considered the two terms you mention want to substitute for eisode and exode, and upon the whole I am disposed to recommend instead of them anode and cathode; which terms may signify east and western way, just as well as the longer compounds which you mention, which derive their meaning from words implying rising and setting, notions which anode and cathode simply and simply. But I will add that as your object appears to be to indicate opposition of direction without opening any hypothesis which may be open to the objection, up and down, which would be arbitrary & consequences of position on any hypothesis, seem to be free from inconvenience, even in their simplest sense. They I hope mention that anodes and cathodes are good genuine Greek words, and the compounds are so for the purpose. If however you would not satisfied with these, I will

FIG. B. EXCERPT FROM WHEWELL'S LETTER OF APRIL 25, IN WHICH THERE APPEARS FOR THE FIRST TIME *anode* AND *cathode*.

of direction without assuming any hypothesis which may hereafter turn out to be false, *up* and *down*, which must be arbitrary consequences of position on any hypothesis, seem to be free from inconvenience even in their simplest sense. I may mention too that *anodos* and *cathodos* are good genuine Greek words, and not compounds coined for the purpose. If however you are not satisfied with these, I will propose to you one or two other pairs. For instance, *dexiode* and *sceode* (*skaiode* if you prefer it) may be used to indicate *east* and *west*, agreeably to Greek notions and usages, though their original meaning would be *right* and *left;* but I should say in this case also, that right and left, as it cannot be interpreted to imply a false theory, any more than east and west, would be blameless for your object. Another pair, *orthode* and *anthode*, which mean *direct* and *opposite* way might be employed; but I allow that in these you come nearer to an implied theory. Upon the whole I think *anode* and *cathode* much the best.

I have already said that I liked most of your new words very well, but there is one which I should be disposed to except from this praise; I mean *zetode*. My objections are these. This word being grouped with others of the same termination might be expected to indicate a modification of electr*ode*, as eis*ode*, and ex*ode*, or an*ode* and cath*ode* do. Instead of this, it means a notion altogether heterogeneous to these, and the *ode* is here the object of a verb *zete*, contrary to the analogy of all the other words. It appears to me that, as what you mean is an element, all that you want is some word which implies an element of a composition, taking a *new* word, however, in order that it may be recollected that the decomposition of which you speak is of a peculiar kind, namely, *electrolytical* decomposition. Perhaps the Greek word *stecheon* (or *stoicheion*) would answer the purpose. It has already a place in our scientific language in the term *stoicheiometry*, and has also this analogy in its favour, that whereas your other words in *ode* mean *ways*, this word stecheon is derived from a word which signifies to *go in a row*. The elements or zetodes are two things which *go* or *seek to go* opposite ways. I might add that, if you want a word which has a reference to your other terms, the reference must be to the process of decomposition by which these elements are obtained. You might call your zetode, an *electrostecheon*, especially if you had occasion to distinguish these elements obtained by *electrolytical* processes from others obtained by *chemolytical* processes, that is, the common analysis effected by the play of affinities. Elements obtained in the latter way might be called *chemostecheons* in opposition to *electrostecheon*. But I am afraid I am here venturing beyond my commission and out of my depth; and you must judge whether your stecheons or zetodes, or whatever they are to be, are likely to require the indication of such relations. If you were to take anode and cathode and adopt stecheon, I think *anastecheon* and *catastecheon* might indicate the two *stecheons*. If you stick to zetode, *anazetode* and *catazetode* would be the proper terms; but perhaps *zetanode* and *zetocathode* would be more analogous to zetode, which is a word that, as I have said, I do not much like.

My letter is become so long that I will recapitulate: *anode, cathode, zetanode, zetocathode* fulfil your requisitions; *anode, cathode, anastecheon, catastecheon* are what I prefer.

With great interest in your speculations, and best wishes,

III

Faraday to Whewell

R Institution
3 May 1834

My dear Sir:

I have waited very impatiently for a proof of my paper that I might send it to you with my letter of thanks for your kindness But I have invoked by that a charge of unthankfulness toward you which however I assure you I do not deserve

All your names I and my friend approve of or nearly all as to sense and expression but I am frightened by their length and sound when compounded. As you will see I have taken *dexiode* and *skaiode* because they agree best with my natural standard East and West I like anode and cathode better as to sound but all to whom I have shown them have supposed at first that by *anode* I meant *no way*

Then *Stechion* I have taken although I would rather not have had the hard sound of *ch* here especially as we have similar sound in both the former words. But when we come to combine it with the two former as *dexio-stechion* and *skaio-stechion* especially the latter I am afraid it becomes inadmissible simply from its length and sound forbidding its familiar use. I think you will agree with me that I had better not form a new word than form one which is not likely to enter into common use.

It is possible that by this time some other shorter word may have occurred for *stechion* if so will you favor me with it If not I think I must strike out the two compounds above and express my meaning without the use of names for the two classes of stechions though they are very very much wanted.

It was the shortness and euphony of zeteisode and zetexode which were their strong recommendations to me.

P.S. Can you give me at the bottom of the pages the Greek derivations &c &c that when you return me the leaves I may have them right for the printer They are of course uncorrected at present.

IV

Whewell to Faraday[15]

Trinity Coll. Cambridge
May 5, 1834.

My Dear Sir,

I quite agree with you that *stechion* or *stecheon* is an awkward word both from its length and from the letters of which it is composed, and I am very desirous that you should have a better for your purpose. I think I can suggest one, but previous to doing this, I would beg you to reconsider the suggestion of *anode* and *cathode* which I offered before. It is very obvious that these words are much simpler than those in your proof sheet, and the advantage of simplicity will be felt very strongly when the words are once firmly established, as by your paper I do not in the least degree doubt that they will be. As to the objection to *anode*, I do not think it is worth hesitating about. *Anodos* and *cathodos* do really mean in Greek a *way up* and a *way down;* and *anodos* does not mean, and cannot mean, according to the analogy of the Greek language, *no way*. It is true that the prefix *an*, put before *adjectives* beginning with a vowel, gives a negative signification, but not to substantives, except through the medium of adjectives. *Anarchos* means *without government*, and hence *anarchia, anarchy*, means the *absence of government:* but *anodos* does not and cannot mean the *absence of way*. And if it did mean this as well as a *way up*, it would not cease to mean the latter also; and when introduced in company with *cathodos*, nobody who has any tinge of Greek could fail to perceive the meaning at once. The notion of *anodos* meaning *no way* could only suggest itself to persons unfamiliar with Greek, and accidentally acquainted with some English words in which the negative particle is so employed; and those persons who have taken up this notion must have overlooked the very different meaning of negatives applied to substantives and adjectives. Prepositions are so very much the simplest and most decisive way of expressing opposition of other relations, that it would require some very strong arguments to induce one to adopt any other way of conveying such relations as you want to indicate.

If you take *anode* and *cathode*, I would propose for the two elements resulting from *electrolysis* the terms *anion* and *cation*, which are neuter participles signifying *that which goes up*, and *that which goes down;* and for the two to-

[15] Todhunter, *op. cit.*, Vol. 2, p. 181.

one to adopt any other way of conveying such relations as you want to indicate.

If you take anode and cathode, I would propose for the two elements resulting from electrolysis the terms anion and cation, which are neuter participles signifying *that which goes up* and *that which goes down*; and for the two together you might use the terms ions, in place of zetodes or stechions. The termination ion is not a substantive in Greek, but it may easily be so taken, as I am persuaded that the [illegible] of the terms you will then have [illegible] in a perfectly genuine form

FIG. C. WHEWELL'S LETTER OF MAY 5, 1834.

THE PORTION REPRODUCED HERE CONTAINS HIS FIRST PROPOSAL OF *anion* AND *cation*.

gether you might use the term *ions*,[16] instead of *zetodes* or *stechions*. The word is not a substantive in Greek, but it may easily be so taken, and I am persuaded that the brevity and simplicity of the terms you will thus have will in a fortnight procure their universal acceptation. The *anion* is that which goes to the *anode*, the *cation* is that which goes to the *cathode*. The *th* in the latter word arises from the aspirate in *hodos* (way), and therefore is not to be introduced in cases where the second term has not an aspirate, as *ion* has not.

Your passages would then stand thus:

"We purpose calling that toward the east the *anode* (ἀνά, upwards, ὁδός, a way; the way which the sun rises), and that towards the west *cathode* . . . (κατά, downwards, ὁδός, a way; the way which the sun sets). I purpose to distinguish these bodies by calling those *anions* (ἀνιόν, that which goes up (neuter participle) which go to the *anode* of the decomposing body, and those passing to the *cathode*, *cations* (κατιόν, that which goes down)." And when I have occasion to speak of these together I shall call them *ions*.

I am so fully persuaded that these terms are from their simplicity preferable to those you have printed, that I shall think it a misfortune to science if you retain the latter. If, however, you still adhere to *dexio* and *scaio*, I am puzzled to combine these with *ion* without so much coalition of vowels as will startle your readers. I put at the bottom of the page the explanation, if you should persist in this.* I would only beg you to recollect that even violent philological anomalies are soon got over, if they are used to express important laws, as we see in the terms *endosmose* and *exosmose;* and therefore there is little reason for shrinking from objections founded in ignorance against words which are really agreeable to the best analogies. The existing notation of Chemistry owes its wide adoption and long duration to its simplicity.

I am afraid you will think I am fond of playing the critic if I make any further objections, otherwise I would observe on your Article 666, that if you are not sure that you will want such words as *astechion*, it is throwing away your authority to propose them. If what I have written does not answer your purpose, pray let me hear from you again, and believe me,

P.S. If, adopting the term *ion* for *stechion*, you do want the negative *astechion*, I do not think there will be any difficulty in devising a suitable word.

[16] Gr. ion, present participle of ieno = to go (Note by M. S.).

* δεξιός on the right hand, and hence, the *east;* σκαιός on the left hand, and hence, the *west.*

V

Whewell to Faraday[17]

Trin. Coll. Cambridge. May 6, 1834.

My dear Sir,

You will have received my letter of yesterday and perhaps will have formed your opinion of it. I still think *anode* and *cathode* the best terms beyond comparison for the two electrodes. The terms which you mention in your last show that you are come to the conviction that the essential thing is to express a *difference* and nothing more. This conviction is nearly correct, but I think one may say that it is very desirable in this case to express an *opposition*, a contrariety, as well as a difference. The terms you suggest are objectionable in not doing this. They are also objectionable it appears to me, in putting forward too ostentatiously the arbitrary nature of the difference. To talk of Alphode and Betode would give some persons the idea that you thought it absurd to pursue the philosophy of the difference of the two results, and at any rate would be thought affected by some. Voltode and Galvanode labour no less under the disadvantage of being not only entirely, but ostentatiously arbitrary with two additional disadvantages; first that it will be very difficult for anybody to recollect which is which; and next that I think you are not quite secure that further investigations may not point out some historical incongruity in this reference to Volta and Galvani. I am more and more convinced that *anode* and *cathode* are the right words; and not least, from finding that both you and Dr. Nichols are ready to take any arbitrary opposition or difference. *Ana* and *Kata* which are prepositions of the most *familiar* use in composition, which indicate *opposite* relations in space, and which yet *cannot* be interpreted as involving a theory appear to me to unite all desirable properties.

I am afraid of urging the claims of *anion* and *cation* though I should certainly take them if it were my business—that which *goes to* the *anode* and that which goes to the cathode appearing to me to be exactly what you want to say. To talk of the two as *ions* would sound a little harsh at first: it would soon be got over. But if you are afraid of this I think that *stechion*, as the accepted Greek name for element, is a very good word to adopt, and then, *anastechion* and *catastechion* are the two contrary elements, which I am sure are much better words than you can get at by using *dexio* and *scaio* or any other terms not prepositions.

[17] Diary, Vol. 2, between pp. 272–273. This letter is preserved at the Royal Institution.

I expect to be in London Friday and Saturday, and if I am I shall try to see you on one of those days and to learn what you finally select.

Without further exchange of letters, Faraday accepted the Whewellian proposals, put the new terms into the proof sheets and the printed version of his paper appeared in June or July, 1834.

VI

Faraday to Whewell

Royal Institution
15 May 1834

My dear Sir—

I ought before this to have thanked you for your great kindness in the matter of the names respecting which I applied to you; but I hoped to have met you last Saturday at Kensington and therefore delayed expressing my obligations.

I have taken your advice and the names used are *anode cathode anions* and *ions* the last I shall have but little occasion for. I had some hot objections made to them here and found myself very much in the condition of the man with his son and ass who tried to please every body; but when I held up the shield of your authority it was wonderful to observe how the tone of objection melted away

I am delighted with the facility of expression which the new terms give me and shall ever be your debtor for the kind assistance you have given me.

Privately, Faraday began to use the new terms at once. The Diary for May 13 refers to *ions* (§ 1754) and contains the statement: "for it is certain that when currents are formed, water is electrolyzed[18] and that oxygen is disposed of at the *anode* in the alkali and hydrogen at the cathode in the acid" (1758). Habit proved too strong when he was alone with his thoughts and he sporadically reverted to the old terms in his Diary. Such backslidings can be found up to November 6, 1835, and in fact as late as October, 1837, Whewell felt impelled to write: "As for positive and negative, I do not see why *cathodic* and *anodic* should not be used, if they will do the service you want of them."[19]

The spelling of anion and cation varied with Faraday, who at times wrote anion and cation, and likewise with Whewell, who used cation (or cathion) because: "The analogy of the Greek derivation

[18] *Electrolyzed* and *Electrolyte* (electron + lyo = to loosen) occur in the Diary (§§ 1738, 1739) as early as April 19, 1834.—J. F. Couch, *Am. Jour. Pharm.*, 95: 806 (1923), discussed the sense in which Faraday used *electrolyte*.

[19] Thompson, *op. cit.*, p. 163.

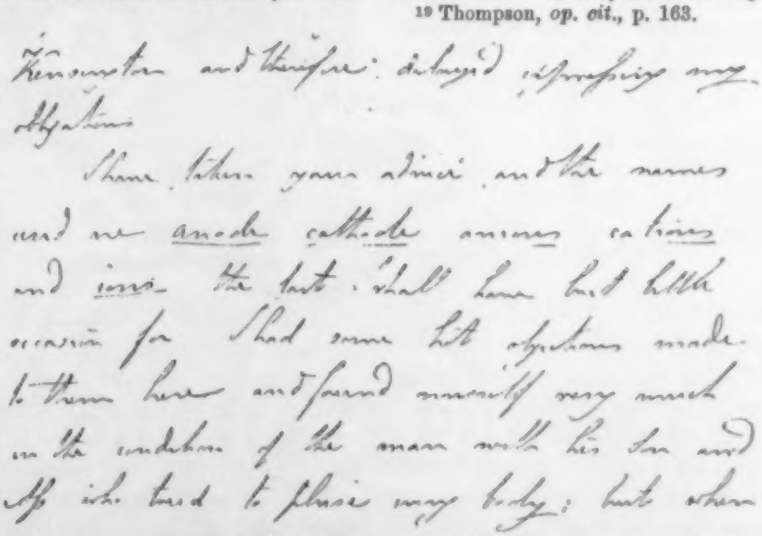


FIG. D. EXCERPT FROM FARADAY'S LETTER OF MAY 15, 1834, SHOWING HIS ACCEPTANCE OF *cathode, anode, anions, cations, ions.*

requires *cation;* but to make the relation to *cathode* obvious to the English reader, and to avoid a violation of the habits of English pronunciation, I should prefer *cathion.*"[20] The variants kathode, kation, etc., were never used by either Faraday or Whewell.

Despite its excellence[21] and even though the terminology was adopted throughout Europe, its complete usefulness did not appear until many years after its birth. As late as 1868 Tyndall could state that while *electrolyte* and *electrolysis* had become established, *anode* and *cathode* "though frequently used, have not enjoyed the same currency as the others. The terms *anion* and *cation*—and the term *Ion*—are still less frequently employed."[22] Not until the theory of electrolytic dissociation began to occupy the attention of the chemical world did the Faraday-Whewell terminology really come into its own. All who deal with the passage of electricity through liquids or gases now find these terms indispensable.

[20] W. Whewell, "History," Vol. 3, 1847, p. 185.

[21] See the commendatory letter of Alexander von Humboldt in Bence Jones's "Faraday's Life and Letters," Vol. 2, p. 30, 1869.

[22] J. Tyndall, *op. cit.*, p. 55.

Whewell's collaboration was again sought by Faraday in 1837, when terms were needed for his work on induction and discharge. *Inductric* and *inductreous* were taken by Faraday "for which with many others I am indebted to a friend." Again in 1850 Whewell was called to his aid, and *paramagnetic* came into being. His service on this occasion was rewarded with: "I, assisted by a kind friend, have thought that a word—not selected with particular care—might be provisionally useful."

Whewell once wrote:

> It is in a great measure by inventing *Technical Terms* that men not only best express the discoveries they have made, but also enable their followers to become so familiar with these discoveries, and to possess them so thoroughly, that they can readily use them in advancing to ulterior generalizations.—These terms soon become part of the current language of all who take an interest in speculation.—They carry with them, in their import, the results of deep and laborious trains of research. They convey the mental treasures of one period to the generations that follow, and laden with this, their precious freight, they sail safely across gulfs of time in which empires have suffered shipwreck and the languages of common life have sunk into oblivion.[23]

[23] "Philosophy," Vol. 1, 1847, p. 51.

THE PROBLEM OF THE CITY

THE FUNDAMENTAL PROBLEM OF HUMAN GEOGRAPHY

By KARL KEKONI
EKENÄS, FINLAND

INTRODUCTION

WHEN we approach the social sciences from the standpoint of human geography, we are astonished at the neglect of the city in current political doctrine. Though the city, directly or indirectly, provides the means for the material and intellectual progress of the mass of the people, yet it plays only a subordinate part in the political life of the nation. It is the country which is supposed to be the citizen's real home and field of action. It is to the state that he owes his faith and allegiance, not to his city. He may remove to the capital or any other city and begin operations which are destined to weaken and damage his former home without incurring any reproach. The structure of the modern state is based on the country and not on the city. In the education of the young, local life and endeavor are more or less neglected, and the process tends to foster nationalism, not local patriotism. In the organization of industry and trade little heed is paid to local interests and aspirations. Factories are closed and ports are abandoned without much concern for the consequence of these measures to the cities. We may indeed characterize the latest development of the modern state as an endeavor to detach the social life in all its aspects from the city and to substitute for local aims and intentions the aspirations and policies of the national state.

The modern neglect of the city stands in the sharpest possible contrast to the importance the city has had in the past for human development and culture. History and archeology teach us that since time immemorial the city has been the center of civilization by which the surrounding region has been raised from barbarism to culture. Science and art, philosophy and higher religion may indeed be regarded as the natural products of city life. The city existed before the state, which was created by it. In classical time the city was the acknowledged bearer of all political and social life within a certain area. According to the Greek theory of the state, as propounded by Plato and Aristoteles, the city and the state were one. Political constructions, resembling our modern national state, which comprises several city centers, were indeed known to the old philosophers but not accepted by them as a satisfactory basis of citizenship. It follows that to the modern statesman the Greek theory of the state is inadequate and of little practical value. This refers naturally to all the political ideas and theories of the state founded on the Greek conception: they all fail to solve or even to treat adequately the fundamental problem of construction, which is essentially a geographical problem.

THE CITY IN ANTIQUITY

Before we go further and show that the Greek conception of the city (*polis*) and the modern idea of the national state are incompatible with each other, it is necessary to give a short account of the position and function of the city in different periods of human development. First we should like, however, to emphasize the fact that even standard works of history do not pay sufficient attention to the city as an agent of progress and civilization. We might, indeed, put the

question whether it would not be advisable to rewrite history and connect the account of events and persons with a number of leading cities and not with the states, which change and vanish, while the cities abide for hundreds and even thousands of years.

A few examples will show the justice of our remark. The usual treatment of Roman history tends to obscure the main fact that the Roman empire and the empire of the city of Rome are almost identical notions. All the aspirations and endeavors told by the Roman analysts, all the victories won and the battles lost, concern in the last resort the status and power of the city of Rome. From many points of view it would give a clearer and truer picture of the course of events to treat the whole story as the tale of a great city. The same refers to the history of the Byzantine empire, which is in reality nothing else than the history of Constantinople. Or again, to take another comprehensive view, when we study the history of the Near East during the Hellenistic period and wonder at the intensity of variety of life and endeavor then displayed by its peoples, and compare it with the backwardness and low level of culture now prevailing in that region, we must remember that in Hellenistic times Asia Minor and Syria were covered by a multitude of cities, each of which had a life of its own and functioned as a real center of commerce and culture. Most of these cities have been destroyed and can no more be reconstructed. Within the new Anatolian state there is only room for a growing capital, some struggling provincial towns and a few seaports, by which to carry on a limited foreign trade.

The glory of Greece and the grandeur of Rome really emanated from a number of wonderful cities, and it was to the destruction of these much more than to the dissolution of the political construction called the Roman empire that the downfall of classical culture was due. The decline of the old centers began with the Roman destruction of the Greek cities in Italy, Sicily and Greece and with the weakening of the city systems of Asia Minor, Syria and Africa. It was continued and finished by the barbarian invaders of the Roman empire, who themselves had no cities and did not understand the idea of citizenship.

The City in the Middle Ages

The Dark Ages following the dissolution of the Roman empire was thus mainly caused by the destruction of the old city system. There could not, indeed, be any progress of civilization or even preservation of the old culture with its science and art, as long as there was no society outside the church where men could find scope for their talents and capacities. In a time when most peoples were wandering about and engaged in raiding and plundering only the warrior and the maker of weapons were held in esteem.

Europe had to wait 500 years before the morning dawned. It was not until the tenth century that the Italian towns began to show signs of revival, and a little later Europe entered on an era of city construction. Within an astonishingly short period the central and northern part of the continent were covered by a network of cities, which immediately began their civilizing activities. New trade routes were opened and connections established with countries and peoples far away in the north, which formerly were wholly outside of civilization. Trading stations were established, churches built and cities founded among the heathen peoples of the Baltic region, which were gradually converted to Christianity. Commerce and industry, which scarcely existed during the Dark Ages, revived and expanded as never before. In order to maintain and extend their trade and influence the cities formed confederacies, such as the

mighty Hanseatic League, whose commercial activities comprised the whole of northern Europe from England to Russia and from Germany to Scandinavia.

The founding of the cities in the eleventh and twelfth centuries of the Christian era may thus be considered the fundamental event of European history. The different parts of the continent were welded together by the synthetic action of the cities. Natural barriers to trade and intercourse, such as the Alps of Switzerland and Tyrol and the forests of Germany and Scandinavia, were overcome by the endeavor of ever-widening commerce. Finally the ocean itself was conquered and connections established with strange lands and peoples beyond the sea. European civilization was thus enriched by new elements, the whole outlook was broadened and the field of action immensely extended. The era of world-wide commerce, of large-scale colonization and of high endeavor in the fields of science, art and religion had set in.

The City in the Period of the Renaissance

The Renaissance thus really meant the reestablishment of the city as the center of civilization. While civilized life and culture during the early part of the Middle Ages and the period of the Crusades were confined to the monasteries and castles of the clergy and nobility, it was now extended to the homes of the burghers of the free city. This development and progress was not limited to the rediscovery and study of classical culture, but comprised the addition of much new thought and experience. Experimental science was born and soon became a powerful instrument of progress in the fields of theoretical and applied knowledge. Thinking and acting, philosophy and technical knowledge, which formerly had been separate fields of endeavor, were united to serve humanity. Materially, the free city became rich and powerful. Stately mansions and noble palaces testified to its wealth and prosperity and bore witness to its free and creative spirit.

At this point of our exposition it should perhaps be stressed that in two of the most important and splendid epochs of human development, the fifth century of classical times and the fifteenth of modern times, civilization and culture were directly related to the life of the free city. It should also be observed that the Renaissance was most clearly expressed in the municipalities of Italy, Germany and the Netherlands, while its influence was much weaker and limited to special branches of life in other countries, like France and England, where national states were in existence. By unification many of the old capitals, such as in France, Besançon, Nancy and Toulouse, had lost their position of political and cultural centers of definite areas and been brought under the authority of the national government, which was centered in Paris. The formation of the national state thus really implied the supremacy of the capital, which became the seat not only of the government and administration, but also of all the leading financial, commercial and cultural institutions of the country. This naturally led to a rapid growth of the capitals, especially Paris and London, while the provincial cities lagged behind and by degrees grew weaker and poorer. The result of this change is now most clearly seen in France, where the provincial cities are small and backward in comparison with the splendid centers of Germany and Italy, which until lately have preserved their position as capitals of natural areas.

The City in the Seventeenth and Eighteenth Centuries

In considering the position of the cities in the period immediately following the Renaissance we must remember that Europe during the seventeenth and

eighteenth centuries was the scene of almost incessant strife. These devastating wars were highly detrimental to the cities. They did not only suffer from fire and sword but also from the loss of capital and men. In many cases they were isolated from their former uplands and areas of influence by new frontiers, which often cut across old trade routes and more and more hindered the internal commerce of Europe.

The City in the Nineteenth Century

Thus the position of the cities in the century 1650–1750 steadily grew more unfavorable. Then, suddenly, the cities derived new energy and life from a mighty source, which for a long time secured their existence and growth. This source of power was implied in the great scientific and technical discoveries and inventions which were accomplished in the latter part of the eighteenth century and led to an immense expansion of industry and trade, accompanied by a rapid growth of population.

The great impetus to renewed endeavor in the fields of industry, commerce and finance thus given was chiefly felt in the cities. Most of the new mills and factories required for the mass-production of cottonware, woollen fabrics, iron tools and countless other objects of everyday use in a progressive society were located in villages and small towns, which, however, soon grew by immigration from the country. But the growth was not limited to the real factory towns. Other groups of cities, especially the ports, profited likewise from the expansion of commerce and shipping which followed the progress of industry. Many a little and dormant country town was stimulated to renewed life by being included in the network of railways which soon covered the country from end to end. Transportation and traffic both by land and sea gave employment and bread to a growing number of people, especially in the cities. Generally speaking, the machine altered the whole life and outlook of man, and created a new civilization, the bearer of which was the city.

The English Factory Town

It was in England that the industrialized society, thus created, assumed its most pregnant form. Thousands of factories were built, wholly altering the natural aspect of large parts of the country. These mills and factories were not, however, evenly distributed over the whole area but assembled in groups comprising the same and related industries. Lancashire thus became the district of cotton mills, West Riding of Yorkshire the home of the woollen industry, Staffordshire that of iron, steel and pottery, while Northumberland, Durham and South Wales became the principal regions of coal-mining. At the center of every district there grew up a large city, mostly consisting of mills, offices and shops and surrounded by an extensive area of slums, *i.e.*, overcrowded, dirty and unhygienic quarters, where a low standard of life prevailed, and poverty, vice and crime were at home.

When we consider the social weaknesses of the early English factory town, we must remember that it had no cultural traditions nor any means to raise its inhabitants to a higher level of citizenship. The Greek idea of the city was totally foreign to a community which was wholly preoccupied with the economic problems of wages, costs and profits. This want of foresight and narrow outlook on life naturally engendered that discontent and social unrest which finally took form in the political upheaval of the middle of the last century and which has continued to trouble and threaten the whole structure of society in England.

Much has in the meantime been done to improve the English industrial town and make it more attractive to its

inmates. Overcrowded and unsanitary areas have been cleared and rebuilt with modern houses, providing more space and light than the old dwelling houses. Electricity has been introduced and put to the service of all at a low cost. Communication within the city area has been much improved by the introduction of mechanical vehicles of different types. Public libraries have been opened, schools of various kinds instituted, art galleries and in the larger cities even universities provided by the help of private munificence for the education of young and old. Yet there is much dissatisfaction and mistrust among thinking citizens. It is asserted in public utterances, in the press and in parliamentary inquiries that the provincial city is being neglected and its position weakened by the progress of central government, and the demand is put forth that the state should be decentralized, giving the city an opportunity to function as the cultural and political center of a definite region.

The German City

As was the case in England, so industry greatly favored the growth of the cities in other European countries, especially Germany. Old centers of commerce and culture, such as Nürnberg, Augsburg, Frankfort and Cologne, which during the Middle Ages had been famous for their trade and industry, their craftsmanship and skilled workers but which had later declined, began to revive under the influence of expanding industry. A number of practically new towns, such as Mannheim, Essen, Elberfeld-Barmen, Hannover, Berlin, Chemnitz and Breslau rose in the valleys of the Rhein, Weser, Elbe, Oder and their tributaries. By the end of the nineteenth century German industry, centered in a number of rapidly growing cities, rivalled and in some branches surpassed English industrial activity. The old Hansa towns, especially Bremen and Hamburg, had grown into great ports, frequented by ships from every part of the globe.

It should be observed that only in exceptional cases did the German industrial city assume the grim aspect of the early English factory town. From the Middle Ages the German city had inherited a strong cultural tradition, which in a great measure tempered and counteracted many of the undesirable features of industrialization. And even after its incorporation in the federal state, the German city retained much of the old spirit of the free city. Moreover, the connection between science and industry, between craftsmanship and manual labor was closer in Germany than in England. The importance of technical education, both elementary and advanced, to the progress of industry was realized in Germany earlier than in England. It must be added that, generally speaking, the German city was better planned, better built and better governed than its English competitor.

Comparing the city systems of Germany and England we must remember that the former country, even after its unification, retained its local capitals. To such splendid cities as Dresden, München and Stuttgart, with their wealth of educational and social institutions, England can hardly show any counterpart except Edinburgh. And it is scarcely possible that such cities will ever rise in England as long as centralization continues to be the leading principle in the building and organizing of the state.

The American City

It is natural that the typical American city does not present the same picture of culture and refinement as do the old centers of Germany and Italy. Though well built and technically progressive and provided with many kinds of educational institutions, it seems to be too much dominated by the idea of business.

The American city does not as a rule function as the political and social center of a certain area, like the local capitals of Germany. It owes its wealth and prosperity almost wholly to its favorable position for industry and trade. The connection between municipal progress and industrial expansion seems so close in America that the problem of the city almost looks like a special problem of economics. But it is in reality far more than that. Whether a city will grow and prosper or languish and decay, depends on many circumstances which lie outside the economic field. Progress presupposes not only energy, ability and farsightedness in the leading members of the city, but also a sense of honor and duty and devotion to the common weal in every citizen.

While it seems hardly possible to exaggerate the part the American city has played in the development of the American nation and the wonderful country which is its home, yet it is evident that it has failed to act up to its opportunities. The causes of its partial failure may be many, but one is certainly that it has neglected to teach citizenship to its members. The significance of the idea has been obscured behind the conceptions and catchwords of party politics and economic strife. It is not generally realized that true progress and real culture mean inner growth, the unfolding of all the good and valuable capacities and qualities in every locality, community and individual, and not the imposition of an outer order and uniformity by the agency of a central government.

The City after the War

Though industry little affected some groups of cities, it was undoubtedly the main factor in the great development the city-system of the world underwent during the nineteenth and the early decades of the twentieth century, including the period of the great war. The war itself highly favored the growth of a large number of cities by stimulating such industries as catered for the armies by providing ammunition, clothing and food. Many old factories were enlarged and new plants provided for the production of explosives and other articles of war, including ships. The industries worked under high pressure from the governments and employed a great number of laborers of both sexes, thus swelling the populations of the cities concerned in the trade.

From the capitalist's point of view the work was highly profitable as long as the war lasted. But at the close of hostilities the war industries were immediately faced with great difficulties. Large factories had to be altered at great cost or wholly scrapped. The products of many industries, which had been greatly expanded during the war, could not be consumed by a public which had been decimated and economically weakened. Large markets had been lost, presumably for ever. Many of the most important industries had to limit their output and rationalize their work, thus creating unemployment on a hitherto unknown scale. All this put a heavy and growing burden on the cities which already were pressed by high rates and large expenditures, consequent on the war.

Centralization

The unsatisfactory position in which a large number of cities, especially in Germany and England, thus found themselves would not have been so serious and disquieting, had the causes of the trouble been of a temporary character. But on examination it was found that the roots of the difficulties lay very deep and were grounded in the new tendencies that more and more dominated the economic development all over the world. During the war several basic industries had been declared national concerns and put under the management of the government. Now it

was urged by national economists and labor leaders that this state should continue even after the war. If we remember that the overwhelming number of factories and workshops in existence have been built by local endeavor and worked by local management, it is evident that this demand really meant a blow to the cities. And even if it has not been carried out in all its extent, it has had a destructive effect in stifling energy and enterprise in the cities.

It must be observed in this connection that the centralization of industry went on, apart from economic theories and political pressure, by way of amalgamation. In this process many of the small factories belonging to the same branch of industry were closed in favor of the larger units, which could be more highly rationalized and more easily financed. This led to a redistribution of industry which adversely affected many provincial towns, while greatly favoring the growth of the capital city. In England, for example, some of the most important industries "moved" southeast in the direction of London, carrying with them great capitals and large armies of workers. It has been calculated that in the period of the last general census 1921–1931 800,000 persons left the northern counties for London and its surrounding districts—one of the largest movements of people in modern times.

The changes in the structure and organization of industry, which entailed great social consequences, were not confined to England, but took place in most European countries, and were the principal cause of the enormous and disproportionate growth of such cities as Paris, Berlin, Moscow, Bucharest, Prague, Copenhagen, Stockholm and Helsingfors.

The method of amalgamation and centralization has not, however, been confined to industry, but applied to many other branches of economic activity. Thus in England, most local banks have been closed and replaced by branch offices of the large London corporations. The same tendency is visible in all European countries, most clearly perhaps in Finland, where practically the whole banking and insurance business is centered in a few large institutions with headquarters in Helsingfors.

Or, to take another important branch of commercial activity, from Liverpool and other shipping centers is heard a loud complaint that the northern ports are suffering by the diversion of traffic to London and its auxiliary ports. The Port of London Authority is spending enormous sums to provide new facilities for the ever-growing traffic on the Thames, while many of the Mersey-docks are empty. Similar tendencies in the shipping of Germany and Italy has led to government interference with a view to attain a more and just uniform distribution of traffic.

Centralization of trade and industry within the modern state has been much accelerated by commercial cooperation and monopolization, which is steadily gaining ground in most countries. Thus in Finland, which is perhaps in this respect the most advanced country in the world, the greatest part of the inland trade is now carried on by two or three great companies, which have their management, head offices and general stores in Helsingfors. The whole liquor traffic of the country is concentrated in the hands of a single company, which imports all the necessary wine and spirits exclusively through the port of Helsingfors.

Concerning the modern organization of inland trade we might add that all the most important products of Finnish industry, such as textiles, glassware, paper, tools and machinery, are distributed by central selling offices in Helsingfors.

When the modern organization of the foreign trade is examined, the same tendencies appear. It is not only in Russia that the export and import busi-

ness is in the hands of a number of trusts, which have their headquarters in Moscow. Many other states are adopting the same system. Thus the export of all the principal products of Finland and Sweden is now managed by large corporations, which have their offices in Helsingfors and Stockholm. The organization of the foreign trade of Germany is developing along the same lines, while England and France are less advanced in this respect.

The main result of the far-reaching changes in the structure and organization of industry and trade, which we have briefly indicated, has been to increase the importance of the capital city and to strengthen its hold on the country at the expense of local centers.

It should, however, be observed that the rapid growth of the European capital during the last decade has not been caused exclusively by the concentration of industry and trade in its vicinity and within its borders. It depends largely, and in some cases principally, on the expansion of the machinery of central government and the growth of national institutions. In the modern capital whole quarters are filled with magnificent buildings, containing ministries and other government offices, law courts, national museums, central libraries and other institutions, which house the great and growing army of officials who more and more completely rule the state.

The Centralized State

From what has been said it should be clear that the organization of the modern state is characterized by centralization and not by capitalism. Every political or social theory founded on the supposition that capitalism is the salient feature of the modern European state is wholly wrong and misleading.

The fault with the state is in its structure and not in the economic system. The organization is proceeding according to a principle which, while favoring the growth of the capital city, weakens the provinces and creates distressed areas and derelict cities.

In fact, if we undertake a survey of Europe from this point of view, we shall find a great and growing number of towns and cities, scattered over the whole continent from Spain to Finland, which have ceased to grow or are in a state of decay. The apparent cause of failure is in most cases dislocation of industry and trade or the gradual detaching of the city from its upland, without which it can not prosper. But these changes are, as we have seen, only the natural consequences of the application of the idea of centralization to the organization of the state.

There is, however, another tendency in the development of the modern state which is contrary to the progress of the city. It is the new nationalism which is fast growing in most European countries. In order to understand its pernicious influence in this respect, we have only to consider that the city must acquire a more or less cosmopolitan character if it is to function as a real center of civilization and progress. It must endeavor to form better connections not only with places inside the national state but also outside the latter. It must seek to enter into closer and more intimate relations with foreign countries and to understand and cooperate with foreign peoples. All this, however, is contrary to the nature of the modern national state, which endeavors to be self-supporting and self-sufficient. In reality, the idea of the state and the idea of the city are contrary notions. The former is morally founded on the ideas of authority and obedience, the latter on those of initiative, energy and cooperation.

CAN WE BE SOCIALLY INTELLIGENT?

By Dr. MAX SCHOEN

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MR. OWEN D. YOUNG is reported to have said that society to-day is in the position of Columbus who, when he started out did not know where he was going, when he got there did not know where he was, and when he returned did not know where he had been. The chaos and confusion that characterize our social household in industry, economics, morality, religion and any other phase of our group life, plus the shouting and tumult of self-designated Messiahs, each with his alleged sure-fire gospel of social redemption, certainly indicate that we are just muddling along in our effort to discover the promised land of social welfare, and that if the journey does not end in disaster it will be by chance and not by choice. Are we then destined to keep on drifting and floundering on the stormy sea of social life and take our chances of either being wrecked or land safely, guided only by the winds and waves of circumstances, or can we set our sails and steer our course towards a definite goal with some assurance that we shall reach it in comparative safety? In other words, can we manage and control our ship of life intelligently, with forethought and foresight, by having captains at the helm whom we can trust, or must we resign ourselves to the belief current in some quarters that social progress by intelligent guidance and direction is a delusion and social drift by muddling along as best we can the only stark reality?

A promising approach to this problem is to examine what constitutes an intelligent approach to a situation and then see whether instances can be cited from past history of any human interests to which such an approach had been made and what fruits it yielded.

What is an intelligent situation? This question is not as puzzling as it may appear to be on the surface. A situation is intelligent when it is under control, when the human mind manages the situation instead of the situation managing the human mind. And control depends upon the operation of two factors in any situation. First is a knowledge of the situation derived from the nature of the situation itself, that is, what the situation in itself actually is, rather than what we would like it to be or what we believe it should be or ought to be. Knowledge that yields control is present only when we act in the light of what we *can* believe on grounds of reliable evidences, and not what we *like* to believe because it is in conformity with our preconceived notions, purposes or prejudices. To accept knowledge because we like to believe it is to harbor fancies and delusions, and therefore to be enslaved to the situation, for a situation will yield to control only when it is respected and not when it is imposed upon. The person who begins to accept the fancies of a day-dream for the facts of reality is taking the first steps to a lunatic asylum. And this is as true socially as it is individually, for society can be, and at times actually is, as insane as an individual. So intelligence, in one of its two aspects, consists of a conscientious effort to get at the facts in the case. But a knowledge of the facts will not in itself result in control, for such knowledge may be used only to carry out a destructive purpose, and consequently, the more knowledge there is the more mischief-producing it may be in its application. We have a capital example of this fact in the socially destructive results that have followed in the wake of the progress of research in the physical sci-

ences. The fault here does not lie in the knowledge, but in its application. The more knowledge that the schemer and plotter possesses in the field of his activities, the more destructive he becomes. Consequently, a second factor in intelligence is an examination of the ends or purposes to be achieved by the knowledge of a situation. This is the factor of self-examination, or knowledge of oneself: the distinction between the worthy and the unworthy, the fit and unfit, the human and the inhuman, and constitutes the ethical or moral phase of intelligence, as the other is the material phase. And the two are inseparable, for where there is no knowledge of the material situation the human being is a victim of the situation by being enslaved to it, and where there is no knowledge of the human situation, or motive, and action in keeping with this knowledge, the human being is victimized by himself by being enslaved to himself. There can be no real control of a situation, and therefore no intelligence, apart from self-control.

Man, then, can be intelligent, for he has the power of knowing both himself and his world, and thus control situations for his welfare. And we have ample historical evidence that where man has used his powers of intelligence he has prospered beyond his expectations or even his fondest dream. The physical sciences have transformed the physical world within the short period of two or three centuries. Sky, earth and water are being increasingly subjected to his will and for his use. And what the biological sciences have accomplished for the physical ills of man is common knowledge. In these we have not been drifting and muddling, but pressing onwards with a clear goal before us and a clear road ahead of us. And all this because of the operation of intelligence. The scientist, whether he deals with the inorganic or organic, obeys both laws of intelligence; he controls himself by not imposing what he would like to believe upon the situation, but accepts what he can believe because it is what the situation tells him about itself. Because he controls himself he is rewarded with the control of the situations he studies, and thus becomes a blessing to mankind.

Obviously, then, our failure to control our social world, as is indicated by the persistent recurrence of some problems and the increasing virulence of others, is an indication of the lack of intelligence in our approach to them. In what way, then, do we fail, and why?

We fail to be intelligent in social affairs in two ways: one by misusing the fruits of the physical sciences and thereby bringing numerous social evils down upon ourselves, and second, by our failure to apply to social ills even as much scientific knowledge about social life as we possess.

A recent editorial in the *New York Times*, in commenting on an address of Sir F. Gowland Hopkins before a meeting of the Royal Society, in which the speaker touched on the question of the scientist's relation to society, makes the charge that scientific research "has something unethical about it because of its disregard of human values," in that "to invent the steam engine, to create vast pools of electric energy and let a nation use them without any regard for the social and economic consequences is a violation of all scientific principles." Now this is an old story. We have heard the tale repeatedly that whereas our material progress as a result of scientific research has been unparalleled, spiritually we have been at a standstill or perhaps even retrogressing. This may be an overstatement of the case. But no one can deny that ethically we have not kept pace with our material advancement and that in the wake of scientific advancement there have followed numerous new social evils, while many old evils have grown in gravity. Wars are not only still with us but science has made them more deadly and devastating.

But should we remain satisfied with stating the case and dismiss it by laying the responsibility at the feet of science, or propose, as some have done, that we take a scientific holiday during which we can catch up on our ethical delinquencies? Is that an intelligent approach to a problem, or is it not rather an evasion of the issue? Certainly, in themselves the fruits of science can not possibly be evil, for science means knowledge, and knowledge is the tool for adequate control. Hence, the evils connected with science can not be due directly to the results of scientific research, but must arise from the misuse of these results. And they are misused not by those who have created them, but by those who exploit these results for private gain. It is then the unscientific, the unintelligent, use of the fruits of the sciences, that brings upon us the evils of which we complain, and not the fruits in themselves. If the leaders in political, industrial, financial or any other social affairs were actuated by the same spirit that controls the leaders in scientific matters, namely, the search for truth, and not merely by schemes for power and profit, the fruits of the tree of scientific knowledge would nourish the social body instead of poisoning it. If a scientist discovers a labor-saving device or a means for increasing production he does not thereby incur the obligation to civilize or humanize the industrialist and manufacturer who might use his discovery in a socially destructive manner. We need intelligence or the spirit of science among those who have the means and the power to misuse the fruits of the labors of the scientist for the satisfaction of greed and avarice. The scientist presents human beings with the gifts for more abundant life, and if these gifts are misused and increase the burdens of life, the fault lies in our stupidity and not in the scientist's wisdom.

Furthermore, not only do the recognized leaders in social affairs misuse the fruits of science, but actively oppose the scientific regulation of these affairs for the common good, by organized propaganda in the interest of the *status quo*. And their propaganda invariably succeeds, at least temporarily, because they clothe their selfish purposes in the garb of altrusim, by proclaiming for their sole motive the promotion of the public good and by branding the advocates of change in the direction of regulation and control as the enemies of the state. We have had recently a capital illustration of the machinations of the enemies of progress by intelligence in the "ganging-up" against the New Deal. Now there is no intention here of defending the policies of the present administration. It is very possible that these policies are erroneous, and even their most enthusiastic supporters do not claim that they are flawless. But one thing is certain, and that is, that most foes of these policies do not oppose them on the grounds that they are fallacious. If their opposition arose from that source they would examine the policies in terms of their own merits, which would constitute a scientific or intelligent approach. But instead of that they appeal to prejudice by proclaiming that the New Deal is contrary to American principles of democracy or constitutes a threat to American standards of living or is a menace to American freedom and personal initiative—all meaningless generalities, empty phrases, but for this very reason the more effective in blinding the public to the real issues and problems at stake. A principle or a tradition can have no soundness in it if the results to which it gives rise are undesirable. Even the Constitution of the United States is not too sacred a document to stand in the way of public and national welfare. What is needed, then, is a critical examination of principles, traditions and even the Constitution, and not oratorical outbursts in their defense, for whatever stands in need of constant defending and can not stand honest ex-

amination condemns itself by that very fact as being false. And those who resort to denunciation and obstruct examination are not so much concerned with preserving the principles they proclaim as with saving their own necks. Their shouting for principles is but a smoke-screen behind which they hide their real motives. We have many illustrations in history of such tactics of the enemies of social progress. The politicians of Athens did not examine the moral ideas of Socrates, but raised against him the hue and cry that he was an enemy of the state, that he preached strange gods, that he was a menace to youth in making the worse appear the better cause. And they succeeded in having him put to death. The priests of Jerusalem raised an outcry of blasphemy and atheism against the spiritually-minded Jesus not so much because they had any genuine concern for spirituality but because his teachings constituted a menace to their power. And they succeeded in having him put on the cross. The Holy Inquisition expressed grave concern for the protection of the infallible truth of Holy Writ as the grounds for hounding and persecuting the scientists of the period, but its concern for Holy Writ meant no more than a determination to assure the control of the human mind by the churchmen for their own purposes. And they succeeded in obstructing the progress of science for centuries. The price for the evils that invariably follow in the wake of such tactics is never paid by the tacticians but by the human family, the innocent and helpless victims of the greed of the few and the mighty.

But why is the human family so easily victimized by those who set out to prey upon it and thereby fails to manage its affairs intelligently? Why does their propaganda succeed in deceiving the human family? The answer is because the propagandist, whether politician, priest, pedagogue or professional reformer, is shrewd in his tactics. His shrewdness is three-fold.

First of all, as has already been hinted, he masks his greed for power and pelf in a cloak of altruism. He never speaks in his own name, but in the name of God or man. He never expresses opinions, but utters oracular truths to be accepted without question. This gives him a weapon against those who doubt his words, by branding them as atheists, unbelievers, enemies of God and man. The politician or priest will not discuss with his opponents. He will smite them, brand them, attack them, denounce them and persecute them. To doubt him is to cast aspersions on divine truth. His voice is the voice of God and the voice of the human cry for salvation. The human family is deceived by him because of his loud voice and louder claims for self-sacrifice and self-denial. The searcher for truth has no inclination to shout from the house-tops, to announce himself a Messiah, to proclaim finalities, for he is too busy searching and is ever in doubt of his findings. Truth is not an accomplishment, but an accomplishing, not a finding but a seeking, not a loud shout, but a quiet, patient and long search. And man is impatient, and therefore easily deceived by fancies presented as finalities. Initially a fancy is more appealing than a fact, since it presents an easy way to a desired end. Its delusive nature makes itself known only in its devastating results, when another fancy is offered as a way out of the dilemma. So the human family has been pursuing will-of-the-wisps, stumbling along, and saved from falling and breaking its neck by no one knows what. Life will persist even against what seem to be overwhelming odds, which is but an indication of what it might attain were it to direct itself by fully conscious means and ends. And it would do so were it not for the plots and schemes of those whose purpose is well served by keeping it in the dark.

The exploiter of mankind succeeds, in the second place, because he offers easy and quick ways to salvation. All we need do is follow his panaceas, and we shall reap a rich harvest. He boasts of being practical, and dubs those who advocate caution as empty dreamers and wide-eyed idealists. If we follow him in any direction in which he leads we shall reach a desirable destination by a leisurely stroll through pleasant country. The way of the dreamer and idealist is slow and laborious; and no guarantee given. We have to blaze the trail, study signs, and we may even get lost and have to find our way back and begin all over again. "Follow me," cries the political Messiah, "and by a mere vote you will enjoy a secure and happy old age." "Follow me," proclaims another, "and by a mere political pressure, quite painless, you will enjoy the fruits of the world now, and not have to wait for old age." "Follow me," shouts the spiritual Messiah, "accept ready-made beliefs, and engage in certain easy, even pleasant practices, make a small contribution for my support and comfort, and you shall have attained peace and prosperity here and bliss in the hereafter." "Follow me," pants the moral Messiah, "conform to my set rules for conduct, at least outwardly, and you shall have public virtue, approval and good business, without regard as to what is in your heart or what you do in private." And if the panacea is not accepted willingly by human beings it is to be forced upon them by any means possible or available. In the meantime each Messiah is busy not only in proclaiming his own panacea and urging its adoption, but in denouncing other Messiahs in his field as false prophets. So the captains are sailing their ships on the troubled sea of society, each steering in a different direction with one hand and with the other shaking a fist at other captains. And the passengers on each ship are certain that they, and only they, are headed for the haven of refuge, and all others are on the way to perdition. But none know definitely just where they are going, why they are going at all, or just how they are to get there.

A third factor that accounts for the success of the predatory individual and group in deceiving the human family, consists of a set of well-established alibis that absolve them from responsibility for the evils created by their operations. These alibis parade in the name of religion and science. We have evils with us, the theologian tells us, not because of the failure of his dogmas to bring peace on earth by creating good-will among men, but because of man's natural and utter depravity, which inclines him to prefer evil to good. The world, he proclaims, is a battle ground between the forces of good and the forces of evil, between God and the devil. Man has the power to choose between them, but in spite of his being urged by the hosts of the Lord to walk the pathway of righteousness and receive a reward, he harkens unto the disciples of the devil and walks in iniquity, just because that is his nature. So those who prey upon human beings and human nature by libelling God and man keep their pie and also eat it: they profit by their depredations and remain innocent of the evils they create.

Or we have evil in the world, say those who find theological excuses outmoded, because of our biological and evolutionary inheritance. We inherit traits from our ancestors that lead us or even drive us directly and inevitably into evil, so we can lay the responsibility at the feet of the dead past. This is a most convenient and easy way out, and all scientific evidences that our social problems are psychological and not biological in origin are of small avail, since a justification for the existence of an evil is far more welcome than an examination of its causes.

Then, if biological heredity fails, evolutionary heredity comes to the rescue. Our evils, we are told, come to us from our animal inheritance, or our instincts. We fight because of our pugnacity instinct. We have industrial strife because of the instinct of acquisitiveness. We meddle and pry into each other's affairs because driven to it by our curiosity instinct. We belittle each other, gossip and blacken character, because of the instinct of envy or jealousy. Scientific evidence to the contrary notwithstanding, namely, that these modes of behavior are habits, and therefore subject to modification and even eradication, we nevertheless cling to them because they justify our doing as we have been doing and desire to continue doing.

So we remain unintelligent in managing our social affairs and go on suffering. But must we continue to do so? The answer is, obviously, that we can help ourselves provided we are willing to face our problems intelligently, by examining their causes and treating them in the light of the causes. And we can do so, since we possess the power of being intelligent and therefore can become actually intelligent. Our ills are of our own making, and therefore we can also unmake them. To do so we must make at least three moves:

1. We must rid ourselves by a process of education of some traditional modes of thought about human beings and human nature which have served the purpose of evading difficulties rather than facing them and dealing with them. Those modes of thought consisted of ideas we liked to believe, and we need ideas we can believe. We have a tool to-day for obtaining such ideas in scientific method, so there is no justification for our dealing with human problems by talk, no matter how attractive or consoling it may sound. Words are valuable only when they are used to report knowledge, and not as substitutes for knowledge. Dogmas, maxims, proverbs, injunctions, pleadings, preachings and warnings might have served some purpose when there was nothing better available. To-day we don't need to impose on man arbitrarily concocted laws and principles, for we possess laws and principles derived from man, which he does not have to be compelled to obey because he already does obey them in that they are the laws and principles of his being. And no law for the guidance of man can have any validity in it unless it is a law that is true to his nature because derived from his nature. Whenever human beings have to be driven to conform to a law it is an indication that the law is false. There is no value in legislation or any other form of compulsion, for all legislation is a palliative, a sedative, not a cure, since it does not touch the cause of the evil, but only suppresses its symptoms, which is dangerous. Human beings can find out from themselves and by themselves as to what is good for themselves, and as they find this out they will also do it without any urging, driving or tempting.

(2) We must drive the money changers from the temple of science and learn to use its fruits for the good of all. The money changers have been and still are with us in other parts of the temple of the human spirit. Good business is still being carried on in the name of religion or morality. But we have been learning to distrust these money changers, and with the waning of their influence human welfare has increased. We have dismissed the theological mind from meddling and dictating in science, and science has rewarded us beyond our fondest dreams. As we learn to prevent the avaricious mind from using the fruits of science for its own purposes we shall find that these fruits will nourish the entire social body and increase its health materially and spiritually. The earth and the fullness thereof which science is increasingly revealing to us and making avail-

able for us need not be used merely to increase the fullness of those already well filled. They can be used to give fullness to all that are willing to work for it. Call this outlook by any name you please to make it appear threatening, but its one real name is humanism. A society in which some human beings have to starve, while others are gorged to suffocation and still keep on gorging, is not a human society nor even beastly, for a beast is through when it has had enough and willing for others to come in and feast. No beast can be as beastly as a human being when he begins to act as a beast. The sciences have provided a feast for all, and therefore let all partake of it in accordance with their normal human needs, in a normally humane manner. He who can not be human has no place among human beings, for he will dehumanize all if permitted to carry on. The person whose "intellect is that of a chameleon who knows when to change his color, of a crab who knows when to dive into the sand, or of a wolf who knows how to stalk his prey" has no place in an intelligently ordered society, and if he succeeds in hiding his chameleon-, crab-, wolf-like activities he will bring about a chameleon-, crab- and wolf-like society.

Finally, we must apply to social ills the knowledge the social and biological sciences have given us, directly or indirectly, about human beings and human nature. This knowledge shows us in unmistakable terms the mistakes we have been making and also how to rectify them. Genetics, anthropology, the various branches of psychology sociology: all throw the bright light of understanding upon many of our most troublesome and persistent ailments like crime, delinquency, insanity, instability of character, thwarted or distorted mental development—all of which are at the basis of our disordered society. Bring up a generation of sound individuals in body, mind and spirit and you have a healthy, sound, harmoniously functioning social group. An individual is in conflict with others because he is in conflict with himself. Remove his inner conflicts, or better, do not permit their occurrence, and you have removed or prevented the causes of outer conflict. Social diseases are like physical diseases. They do not merely happen, they are caused. And the biological and social sciences point out the causes. If we fail to use this knowledge we have neither nature nor some mysterious divine or devilish forces to blame, but only our own inertia.

In sum, we can be socially intelligent if we deliberately and conscientiously set out to be so. All we need do is realize the causes of our unintelligence and proceed to deal with the evils they have brought down upon us by placing our confidence in the social leadership of those persons who have proven themselves worthy of confidence by the constructive fruits of their quiet and relentless labors, namely, the great dreamers and idealists of the ages. Everything we possess to-day of positive value to man has come to us from them, in spite of our disregard of them and in spite of the opposition to them of those to whom truth is a menace. We can establish them in positions of leadership and trust implicitly in their guiding hand. We have had enough experience, bitter experience, throughout centuries of suffering and anguish to realize the soundness of Plato's proclamation some 2,300 years ago that, "Until philosophers are kings, or the kings and princes of this world have the spirit and power of philosophy, and political greatness and wisdom meet in one, and these commoner natures who pursue either to the exclusion of the other are compelled to stand aside, cities will never have rest from their evils—no, nor the human race, as I believe—and then only will this our State have a possibility of life and behold the light of day."

GROUP THEORY FOR THE MILLION

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GROUP theory is not explicitly included in the recent unique and popular book entitled "Mathematics for the Million" by Lancelot Hogben, F.R.S. This may be due to the fact that this interesting book emphasizes the body of mathematics more than its soul. It unfortunately assumes a somewhat contemptuous intolerance for all mathematical work which is not undertaken directly for the improvement of social conditions, and hence it overlooks one of the mainsprings of mathematical progress during all the ages; *viz.*, the search for new truths and the delight in seeing things from a new and more general point of view. Mathematics for the million naturally devotes little space to the most elementary parts of this subject, which are of interest to a much larger number of people. It also properly excludes the advanced developments of this subject, since these are of interest to only a small number.

There is, however, a considerable body of group theory knowledge which may reasonably be regarded as belonging to the mathematics for the million at the present time. This includes the knowledge of the cyclic groups as well as of a number of non-cyclic ones. Among the latter the one which involves four operators is the simplest, and its usefulness is attested by the fact that it appears under five entries in the recent second edition of "Webster's New International Dictionary" (1934), as follows: "anharmonic group," "axial group," "cross-ratio group," "four-group," "quadratic group." As an abstract group it is characterized by the fact that in addition to the identity it is composed of three operators such that the product of every two is the remaining one and the repetition of each is equivalent to the identity. It is illustrated by the movements of space which transform a general plane rectangle into itself. The three movements of period two are the rotations around the lines of symmetry of this rectangle through 180°, and the rotation through the same angle around the perpendicular to the rectangle at its center.

The circle embodies every cyclic group, but it embodies much more. The properties of the circle which seem to have first attracted attention, such as the determination of its approximate area and the approximate ratio between its length and the length of its diameter, have nothing in common with group theory. On the other hand, its generation by the repeated rotation through the same angle measured by a number and the different possible selections of the operators which may be used to generate these rotations are group theoretic questions which received attention only in comparatively recent times. This seems to be due to the fact that in modern times there has been a growing tendency to substitute more and more the study of the dynamics of the phenomena in place of their static properties. The idea of evolution dominates more and more the scientific thought, and this idea is the source of the modern emphasis on group theory in mathematics.

It would be difficult to find a more forceful illustration of the fundamental fact in the history of mathematics that the developments of this subject are largely affected by the spirit of the age than is furnished by the emphasis on

group theory during recent times. In particular, the cyclic group might have been emphasized in the study of the circle even in early times, but it was not until the nineteenth century that this group received much attention in connection with this study. The growing emphasis on this group was also largely due to the fact that during the nineteenth century it became more and more clear that a large number of mathematical problems are inherently reducible to non-cyclic groups, and hence the study of the cyclic group was seen to be the natural entrance to various broad realms of mathematical ideas. Family connections in mathematics have been no less influential in bringing certain subjects temporarily into the limelight than similar connections in the social world.

The definition of the concept of group is so very simple that one might at first suppose that little could be accomplished by the use of this concept. In addition to the fact that when three or more elements of a given set are combined, two at a time, the associative law is obeyed, it is only required that when any two of the symbols in the equation $xy=z$ are replaced by the same or by two distinct elements of the set then the third of these symbols can be replaced by one and only one of the elements of the set. Contrary to a widely quoted statement, the natural numbers do not constitute a group when they are combined by multiplication, as may be seen by replacing z in the given equation by a prime number and replacing one of the other symbols of this equation by a different positive integer. The common integers, including zero, obviously constitute a group according to the given definition when they are combined by addition, zero being the identity element. This constitutes one of the most useful groups in the entire field of group theory.

Notwithstanding the fact that the definition of the concept of group is very simple and can be stated in a few words various writers have failed to observe even these mild restrictions in the use of the term group, as may be seen from the reference to the natural numbers in the preceding paragraph. This could be more easily tolerated if it could be proved that a widely useful abstract theory could be based upon the definitions employed by them. Such a proof has never been given so that there is to-day essentially only one abstract group theory, namely, the one which is in accord with the definition quoted in the preceding paragraph. This is especially true as regards groups of a finite number of elements, which have been primarily in mind in the present article. It is well known that each of these groups presents itself once and only once among the regular permutation groups, and hence these groups appear in a concrete form as well as in an abstract form.

Every child uses groups long before it is confronted with the name of this concept as a mathematical term. When the face of the clock bears a certain number of numbers, such as 12 or 24, to represent the hours, it is clear that when a certain number of hours is added the result is equal to one of these hours with respect to a given modulus. That is, the numbers on the face of a clock constitute a cyclic group with respect to the modulus which is equal to the largest of these numbers, and this largest number is the identity of this group. Similar remarks clearly apply to the number of the days of the week or year. Why, then, did people not always take an interest in these groups as mathematical concepts and consider the order of their operators, the number of their generators, the number of their subgroups, etc.? These group theoretic questions when applied to the face of the clock appear at first to be of minor importance. They become

very significant only when they are viewed from a higher point of view as related to a subject of great usefulness.

The man who sees the cyclic group on the face of the clock obviously has a richer life than the one who sees only the numbers thereon. Similarly, the cyclic group becomes much more impressive when viewed as a corner-stone of the large edifice of group theory than when it is considered by itself. The movements of space which transform various regular geometric figures into themselves exhibit other important parts of this edifice. Notwithstanding the fact that these figures have been studied for thousands of years, their groups were not explicitly noted until recent times, and this is another forceful illustration of the fact that the developments in mathematics have been largely influenced by the scientific spirit of the times when these developments were made. The movements which transform the regular plane polygon of n sides into itself constitute the dihedral group of order $2n$, composed of the cyclic subgroup of order n formed by the movements which do not interchange the sides of the plane in which the polygon is located and the n rotations through 180° around the lines of symmetry of this polygon.

An interesting property of the group of the regular plane polygon of n sides is that it is generated by two of its rotations through 180° around two distinct lines of symmetry irrespective of the value of n. From the standpoint of abstract group theory it is important to note that whenever two operators of order 2 have a product of order n then these operators generate the group of movements of the plane regular polygon of n sides. This is an instance of the remarkable simple abstract definitions of the group of movements of the regular figures in elementary geometry. The facts that two group operators of the order 2 invariably generate the dihedral group whose order is twice the order of the product of these operators and that there is one and only one such group of every even order are primary facts in the theory of groups and exhibit in part the fertility of the simple definition of an abstract group. While there is one and only one cyclic group of every order there is one and only one dihedral group of every even order.

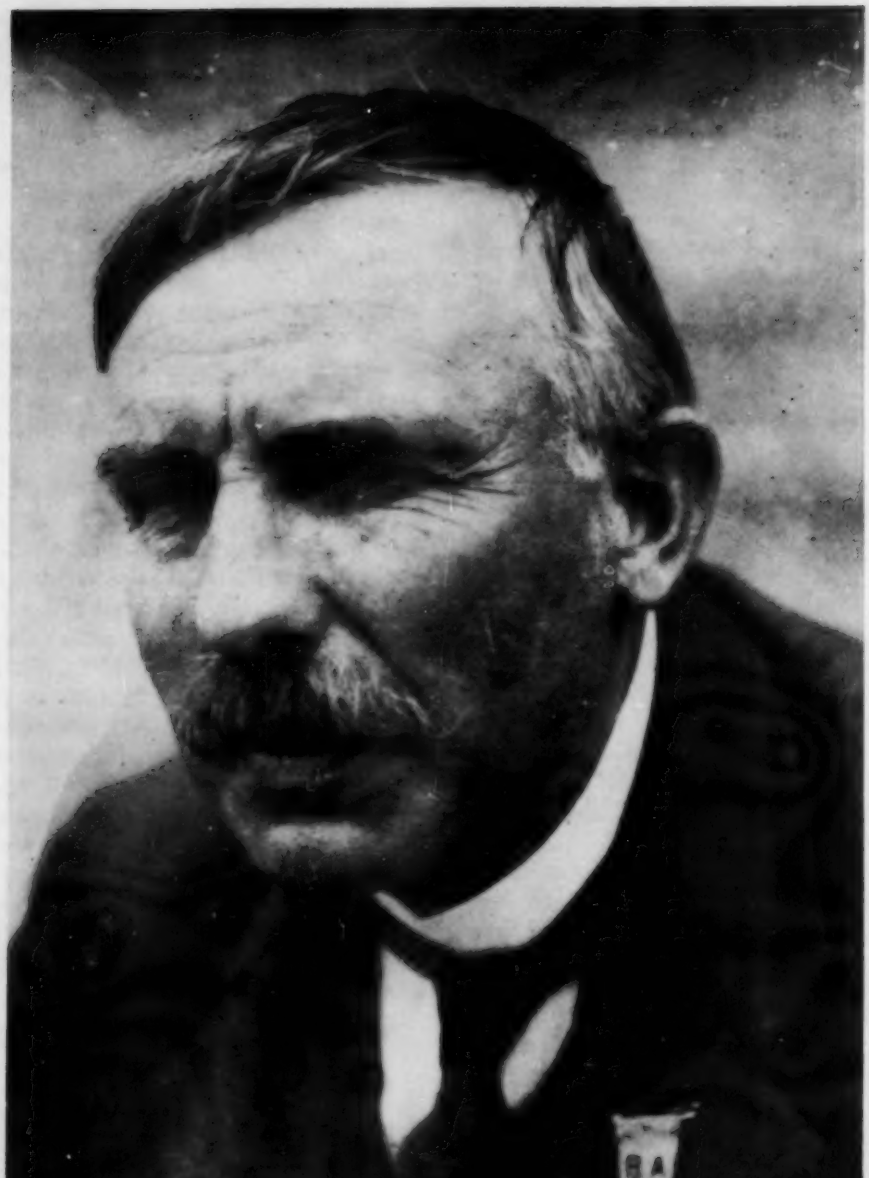
The groups of the regular polyhedrons of elementary geometry are also remarkable for their simple abstract definitions, which were first pointed out by a noted Irishman, W. R. Hamilton, in 1856, after these solids had been studied for more than two thousand years. Abstractly, these groups are separately generated by two group operators of orders 2 and 3, respectively, whose product has one of the following three orders: 3, 4, 5. When this order is 3 there results the group of the 12 possible movements of the regular tetrahedron; when it is 4 there results the group of the 24 possible movements of the cube as well as of the regular octahedron, and when it is 5 there results the group of the 60 possible movements of the regular icosahedron as well as of the regular duodecahedron. The remarkable simplicity of the definitions of these groups from an abstract point of view suggests an explanation of the attractiveness of these solids since the times of the ancient Greeks and adds greatly to this attractiveness from the more advanced point of view.

The basis of symmetry is the group of movements which transforms the symmetrical figure into itself, and symmetry has always played a fundamental rôle in intellectual work. This is illustrated by the facts that the square was most commonly selected even by the ancients as the unit of surface measure, while the cube has been most commonly chosen as the unit of solid measure. On the other

hand, the groups of movements of the square and the cube failed to receive explicit notice until recent times. These groups are, however, not mainly of interest because they throw light on the selection of these units of measure, but because they exhibit connections relating to various other subjects. Their connection with the common units of measure seems, however, to justify the view that they are for the million and should tend to deeper intellectual insight on their part, at least with the advance of enlightenment.

It seems natural to inquire how the mathematical world first gained an entrance into the theory of groups as contrasted with the use of special groups, which was very early as noted above. This unconscious entrance is apt to throw light on how the modern student can most easily secure a knowledge of this growing and widely used theory. The proof of the fact that when a group appears within a group the order of the latter is divisible by the order of the former seems to have furnished the first solid foundation for the theory of our subject. This fact is known as the theorem of Lagrange (1736–1813), although Lagrange could obviously not have proved it in its general form, since he died before the theory of abstract groups was founded. It is an illustration of many cases in the history of mathematics where a wise start is glorified by the successful labors of succeeding generations. In fact, the entire theory of abstract groups may be regarded as a glorification of the earlier developments in the theory of permutation groups.

The theorem of Lagrange suffices to prove that there is only one group of a given prime order, since every operator of such a group, besides the identity, generates the entire group because the group contains no subgroup besides the identity. A proof of the theorem of Lagrange results very easily from the rectangular arrangement of the operators of a group in which the first row is composed of the operators of the given subgroup. A second important entrance into the theory of groups was effected by the proof of the fact that when the order of a group is divisible by a given prime number then the group contains a subgroup whose order is equal to this number. The famous French mathematician, E. Galois (1811–1832), who is the only noted mathematician who died before he was twenty-one years old, stated this theorem without recording a proof thereof. After it was proved by A. L. Cauchy (1789–1857), a solid foundation for progress was laid and many writers built thereon and are still actively engaged in adding to the superstructure.



—Photograph taken at the Toronto meeting of the British Association for the Advancement of Science, August, 1924

LORD RUTHERFORD OF NELSON

THE PROGRESS OF SCIENCE

RUTHERFORD

THE name of Rutherford will be forever identified with radioactivity and the nucleus of the atom. In a scientific generation whose great problem was the structure of matter, Rutherford directed the new-found powers of nature to uncover her innermost secrets. Rutherford approached his scientific problems with vigorous directness, steering straight to the heart of the matter, using whatever tools were most suitable, pressed on by a burning urge to find the truth. His genius was to plow through a tangle of data and guesses and bring into obvious view the underlying facts. Himself a great leader in science, he has passed the blazing torch to hundreds of younger men.

Lord Rutherford was born in 1871 as Ernest Rutherford, in the little town of Nelson, in the South Island of New Zealand. He made a brilliant record at Canterbury College and New Zealand University, and went to Trinity College, Cambridge, in 1894. His studies during this first Cambridge period included work on electric waves, in which he developed a detector of increased sensitiveness and important observations on the ionization of gases, in collaboration with J. J. Thomson. From Cambridge, Rutherford went to McGill University as Macdonald professor of physics, where between 1898 and 1907 he did his most important work on radioactivity. The next period of twelve years was that in which he developed the nuclear concept of the atom. As Langworthy professor at Manchester, he not only performed his own brilliant experiments on the scattering of alpha rays, but also stimulated the equally fundamental work of Bohr and Moseley. After the war, he accepted an urgent request to go to Cambridge as Cavendish professor, where he was destined to make the Cavendish laboratory, already notable for the great researches of Maxwell, Rayleigh and Thomson, preeminent in the world-wide attack on the structure of the nucleus.

If the record of his discoveries is to be paralleled in the annals of physics, it will be only by a Newton or a Faraday. Consider some of them: Working with J. J. Thomson on the effects of x-rays, Rutherford gave the first convincing proof that electric current passes through gases because of the presence of charged "ions." This was the foundation stone of our knowledge of the mechanism of conduction of electricity through gases. His brilliant researches established the existence and the nature of radioactive transformations. He was the leader in the analysis of the rays from radioactive substances into the alpha, beta and gamma rays, and the identification of these rays as doubly charged helium atoms, electrons and electromagnetic radiation, respectively. An incident in this work was his measurement of the electronic unit of charge with a precision many times greater than that of earlier determinations and adequate for the contemporary needs of the electron theory. Using alpha rays as his tool, he established the theory that the atom has a concentrated, electrically charged nucleus which possesses nearly all the atom's mass. He tested the laws of electric force for sub-atomic distances, and measured the electric charges of his atomic nuclei. That these nuclei were not elemental things, he proved by disintegrating them with alpha rays, discovering in the process that the proton, the nucleus of the hydrogen atom, is a component of the heavier atomic nuclei. Under his immediate encouragement were performed Moseley's remarkable x-ray experiments that showed the

—Photograph taken at the Toronto meeting of the British Association for the Advancement of Science, August, 1924, by Arthur H. Compton

LORD RUTHERFORD AND SIR WILLIAM BRAGG

meaning of atomic number in terms of nuclear charge, Chadwick's discovery of the neutron which forms a part of the nucleus, Cockcroft's artificial disintegration of nuclei and Niels Bohr's development of his theory of the atom. A large part of the development of modern physics thus occurred within his brain and was established by tests made with his own hands.

Strength and contagious enthusiasm were outstanding characteristics of Rutherford. His interest was an inspiration to those who worked with him. While not infallible in his inferences and conclusions, his clear physical intuition was at times almost uncanny in its accuracy. His powerful physique suggested a lethargy that was belied by his nimble wit, which on more than one occasion was effective in exposing the pretensions of too careless theorists.

Rutherford's great powers were not used in the laboratory alone. In his later years, he took an active part in applying science to the public welfare. As president of the British Association for the Advancement of Science and for a number of years also of the Royal Society, he was an effective public exponent of science.

Universities, societies and academies at home and abroad were pleased to have Rutherford accept their honors. He was knighted in 1914 and received the Order of Merit in 1925. It was with no little hesitancy that in 1931 he allowed himself to be created first Lord Rutherford of Nelson. His characteristic democracy, however, enabled him to keep close to his scientific colleagues, and he felt that he should not make it too difficult for his nation to recognize the importance of the contribution that was being made by science.

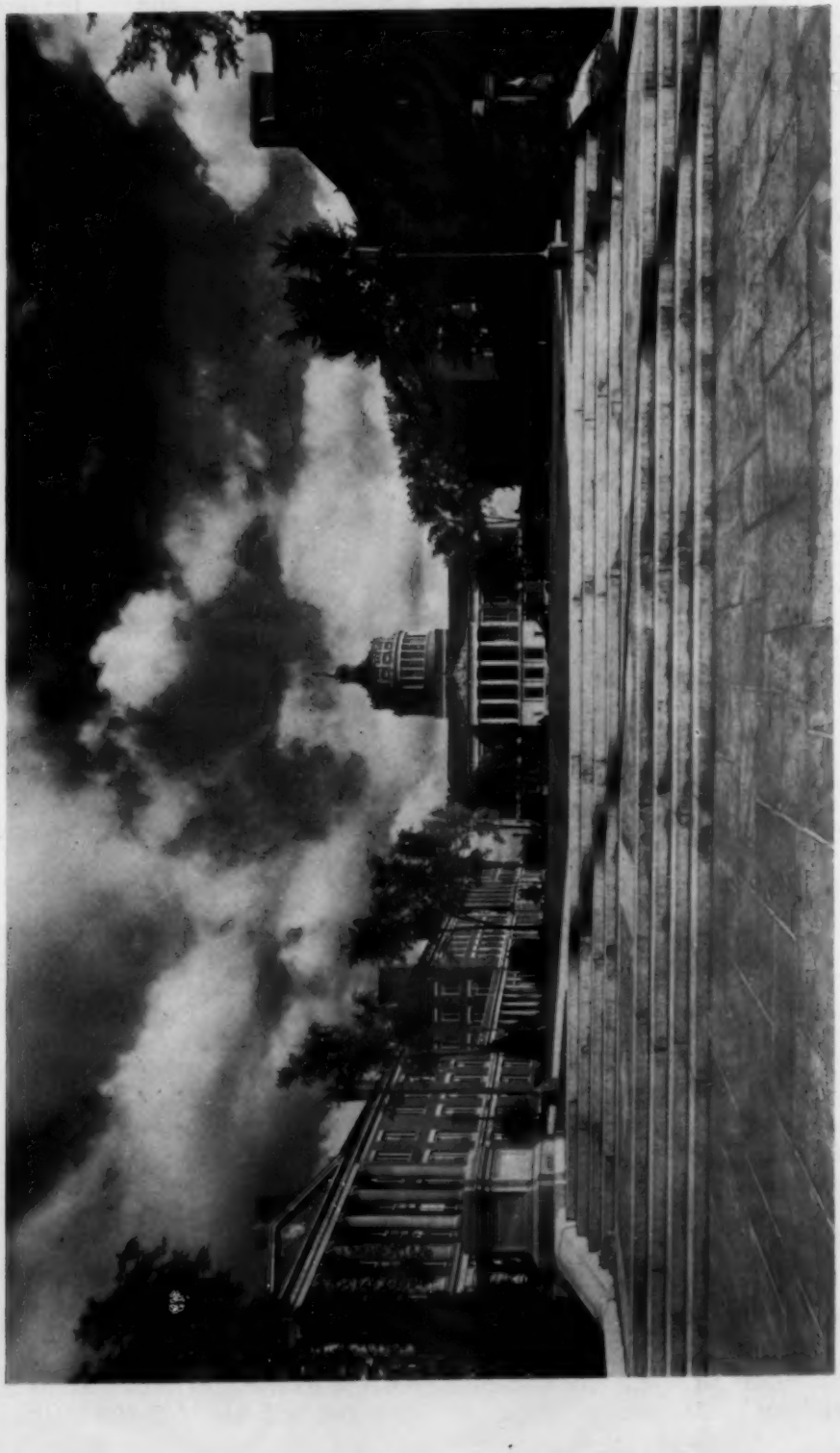
According to a recent British commentator, Rutherford "was by far the greatest living experimental scientist, and the greatest the world has seen since Faraday." This is a judgment that will be shared by most of those who know his work. In an age whose great achievement is its science, it would be fair to consider him as having been the world's first citizen.

ARTHUR H. COMPTON

THE ROCHESTER MEETING OF THE NATIONAL ACADEMY OF SCIENCES AND PRESENTATION OF THE COMSTOCK PRIZE TO PROFESSOR LAWRENCE

THE 1937 autumn meeting of the National Academy of Sciences was held at the University of Rochester, N. Y., on October 25, 26 and 27. The thirty-eight members of the academy who were present found themselves in a city of especial interest to men of science, by reason of its location in a region of great geological and historical importance, as well as its possession of remarkable technical industries and a rapidly developing university. The meeting was comfortably accommodated in the Strong Auditorium of the River Campus, beside the Genesee River, and surrounded by the new laboratories and classrooms of the College for Men.

The members were officially welcomed by President Valentine, to whom response was made by President Lillie of the academy. The scientific program, which occupied three mornings and one afternoon, comprised thirty-four papers. Of these only nine were presented by visiting members and guests, the rest coming from the various departments of the local university (with one from the Research Laboratories of the Eastman Kodak Company). The material presented was therefore predominantly biological, reflecting the activity of the young but important medical school and the recently reorganized biological department. Mathematics, physics, chemistry and geology were represented by ten contributions of which three came from the Institute of Optics of the uni-



THE MAIN QUADRANGLE OF THE UNIVERSITY OF ROCHESTER

versity and of the department of physics, also newly reorganized. The daily and weekly press took more than usual interest in the proceedings, sending a very competent corps of journalists, who reported many of the contributions at length.

On the afternoon of October 25 the members were received at tea by Dr. and Mrs. Valentine at Eastman House, the residence which the late George Eastman bequeathed to the university to be a home for its president. In the evening, in place of the usual lecture, the Symphony Orchestra of the Eastman School of Music gave a special concert in the great Eastman Theater, open to the public but held in honor of the members of the academy, for whom the mezzanine gallery was reserved. Before an audience of 1,400, the young musicians played with remarkable enthusiasm and technical skill under the leadership of Dr. Howard Hanson, director of the school, performing among other works Dr. Hanson's own "Romantic Symphony."

On the afternoon of October 26 there were inspection trips to two of the scientific industries upon which Rochester's fame is largely based, the Bausch and Lomb Optical Company and the Eastman Kodak Company. At their respective plants the visitors were divided into small groups and shown the work in progress in the research laboratories.

On the second evening of the session, October 26, a subscription dinner was held at the Genesee Valley Club. Arthur Parker, director of the Rochester Museum of Arts and Sciences, essayed as after-dinner speaker the difficult, even dangerous task of prophesying the future not only of the science of man but of man himself. The dinner was the occasion of the presentation of the Comstock Prize for achievement in the field of electricity to Dr. E. O. Lawrence, of the University of California. An address in explanation of the award was made by Dr. W. D. Coolidge, to which Dr. Lawrence responded in words of noteworthy dignity and charm. In the course of his remarks Dr. Coolidge said:

> Prior to 1919, we had no definite information concerning the interior of the nucleus of the atom. We knew that it had a positive charge equal to the sum of those of its extra-nuclear electrons. In addition to this, it was clear that the nuclei of the various chemical elements were all constructed from the same building blocks. But nothing was known about the nature of these blocks nor of the forces holding them together. The constitution of the nucleus was, then, one of the most fundamental problems that had ever presented itself to physical science.
>
> It was Lord Rutherford who opened the door to this rich storehouse of scientific knowledge. By shooting alpha particles into nitrogen he was able to disintegrate the nitrogen nucleus with the formation of protons and an oxygen isotope. His classical experiment was followed by the bombardment of other elements with natural alpha particles and, in this way, the nuclei of nearly all the lighter elements up to calcium were transformed. With one exception, however, all attempts to transform the nuclei of the heavier elements had failed. Thus arose the urge to produce, artificially, particles having a higher energy content than those projected spontaneously from the radioactive elements. It was clear that, given sufficiently high voltages, such particles could be produced, provided suitable tubes could be developed to withstand these difficulties and seemingly serious limitations.
>
> Dr. Lawrence envisioned a radically different course—one which did not have those difficulties attendant upon the use of potential differences of millions of volts. At the start, however, it presented other difficulties and many uncertainties, and it is interesting to speculate on whether an older man, having had the same vision, would have ever attained its actual embodiment and successful conclusion. It called for boldness and faith and persistence to a degree rarely matched.
>
> In the magnetic resonance accelerator, or cyclotron, which Dr. Lawrence has created and developed, positively charged particles are accelerated so many times, as they circle about in a strong magnetic field, that they acquire energies of millions of electron volts, even though the actual accelerating potential difference is only a few tens of thousands. Not only this, but the limit to the particle energies which can be generated in this way is not yet in sight.
>
> Many serious difficulties have arisen and been successfully overcome. There has been, for example, the very vital problem of protecting human beings in the neighborhood from the extremely penetrating and dangerous radiations

DR. ERNEST O. LAWRENCE

PROFESSOR OF PHYSICS AND DIRECTOR OF THE RADIATION LABORATORY AT THE UNIVERSITY OF CALIFORNIA.

produced by the cyclotron discharge. Without much intelligent care many workers might well have been seriously injured. The value of the new tool is attested by its world-wide adoption and by the variety of scientific uses to which it is being put.

Dr. Lawrence has not only created and developed the cyclotron, but, in addition to this, he has been in the forefront of those actually using high energy particles in the assault on the nucleus. With high energy deuterons he has bombarded various elements, nearly all of which have been disintegrated by these particles, in most cases giving rise to new radioactive isotopes. These new artificial radioactive elements, which will soon be available in large quantities, can be used to investigate not only other nuclear phenomena, but also the mechanism of chemical and biological processes. They may also find important therapeutic uses.

THE INDIANAPOLIS MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

INDIANAPOLIS, INDIANA, is nearer the center of population of the United States than any other large city. It follows from the technical definition of "center of population" that there is no other city to which all the people in the country could go with so small a total of miles traveled. For this reason Indianapolis is an appropriate place for the annual meeting of the association, which will be held from December 27, 1937, to January 1, 1938.

There are, however, better reasons for holding the meeting of the association in Indianapolis. For example, it is one of the greatest railroad centers in the United States, having direct connections by through trains from the east and the west, from the north and the south. It is the capital of the State of Indiana, a fine city with a population of about 400,000. It is well supplied with modern hotels, it has a large number of places suitable for meetings near the center of the city, and it has excellent transportation. In these respects Indianapolis is exceptional, for its hotel, theater, banking and retail business district surrounds a circular plaza from the center of which rises an imposing soldier's and sailor's monument.

Since the American Association for the Advancement of Science through its fifteen sections and one hundred sixty-two affiliated societies covers practically all of pure and applied science, it appropriately gives a large amount of attention to the interrelations of the sciences and to the effects of science upon society and human beings as individuals. Several of the principal addresses are on such subjects.

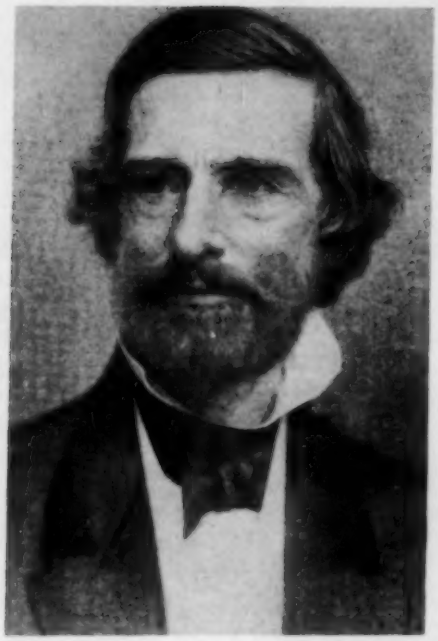
"Science and Ethics" is the title of the retiring presidential address of Dr. Edwin G. Conklin of Princeton, which will be delivered on Monday evening, December 27. All who have been interested in the question whether science lays a new and better foundation for ethics will eagerly await Dr. Conklin's address. On Tuesday evening, December 28, Dr. Irving Langmuir, of Schenectady, New York, will deliver the annual Sigma Xi address, his subject being "The Physiological Significance of Moni-Molecular Films." In this address Dr. Langmuir will lead his audience out to the frontiers where science is discovering the nature of the physiological processes. Dr. George Lyman Kittredge, professor emeritus of Harvard University, will deliver the annual Phi Beta Kappa lecture on Wednesday evening, December 29. These Phi Beta Kappa addresses were inaugurated for the purpose of emphasizing the essential relationships that exist between science and general culture. Dr. Kittredge has chosen for his subject, "Shakespeare and the Critics." In addition to these addresses by distinguished scholars, there will probably be presented in excess of one thousand papers in the symposia and other sessions of the Indianapolis meeting. Only a few years ago not as many scientific papers were written in the United States in an entire year. Truly, the present rapid advance of science is one of the most remarkable phenomena in the whole history of the human race.

F. R. MOULTON

THE LAURA BRIDGMAN CENTENARY

DURING the autumn months of 1937 the Perkins Institution in Watertown, Mass., that venerable and honorable pioneer school for the blind, celebrated the centenary of the admission within its precincts of Laura Dewey Bridgman, the first blind deaf-mute to be taught the use of language.

When the first director of the institution, Dr. Samuel Gridley Howe, that doughty champion of human rights, heard of this triply handicapped child



SAMUEL G. HOWE, ABOUT 1859

of eight years, leading an isolated existence in her farmhouse home in Hanover, N. H., he determined to achieve what in similar instances learned physicists had declared to be impossible, by penetrating to her dormant mind.

He easily persuaded her parents to entrust Laura to his care and set himself to the task of releasing her from the dark silence in which she was enshrouded. It was a trackless waste which confronted him, without guidance or precedent, and the path for the child's awakening, and for those coming after her, had to be hewn out by his own unaided efforts.

He has given a careful and authentic account of the long and tedious process by which, step by step, beginning with simple objects in daily use and the labels bearing their names in embossed type, he brought her to a realization of the connection of article and its name and, later, to the possibility of communication with those about her and, eventually, to full participation in normal life and activity around her, to appreciation of abstract truths and deep religious faith.

THE BRIDGMAN HOMESTEAD
ETNA, NEW HAMPSHIRE, WHERE A BRONZE TABLET IN MEMORY OF LAURA BRIDGMAN WAS UNVEILED ON OCTOBER 20, 1937.

LAURA BRIDGMAN

Although there were many visits to her family in Hanover, Laura's life was centered in the institution which had opened its doors to her. There she found friendly companionship and a host of interests—reading, a voluminous correspondence, the making of exquisite articles of handwork, a share in plans for helping other handicapped children, even the teaching of newcomers to the

JAMES AND MARGARET ALLEN
DEAF-BLIND TWINS NOW AT THE PERKINS INSTITUTION FOR THE BLIND.

school—which kept her alert and happily occupied throughout her life, which came to a close in 1889, at the age of sixty years.

Her achievement was a veritable triumph for Dr. Howe. When, with Mrs. Howe, he traveled in Europe in 1843, he was everywhere acclaimed as Laura's deliverer, for the news of her awakening had been bruited abroad, especially through Dickens's fervid recital of the fact in his "American Notes," which led directly in after years to Helen Keller's emancipation. Dr. Howe was indeed Laura's deliverer and also a devoted foster-father, who cherished her as the child of his heart to the end of his life in 1876.

Many are the ways in which the memory of this first deaf-blind pupil is being kept alive, chief among them being a tablet, suitably inscribed and affixed to a boulder near her home in Hanover, and the assignment of her name in perpetual remembrance to one of the cottage dwellings of the institution which she had lovingly christened "Sunny Home."

The instruction of this shut-in being was important pioneer work, opening a new channel of human enterprise and endeavor. Its present-day methods, however, are no longer those of Dr. Howe, since his early experiments have been superseded in recent years by the more flexible and useful oral method, with articulation as the corner-stone. A well-

LAURA BRIDGMAN
FIRST DEAF-BLIND PUPIL, TEACHING OLIVER CASWELL, ANOTHER DEAF-BLIND PUPIL AT THE PERKINS INSTITUTION FOR THE BLIND, ABOUT 1844.

planned and finely equipped department for the deaf-blind has been established at the institution, through specific, voluntary contributions, and no effort is spared to lead its pupils into the joy of life and thanksgiving which, with far less reason or opportunity, was Laura Bridgman's in full and satisfying measure.

A. G. F.

DEDICATION OF A MONUMENT TO PEARY AT HIS BIRTHPLACE

On the afternoon of October 15 a life-size bronze statue of Admiral Peary was unveiled at Cresson, Pa., close to the little house in which he was born on the sixth of May, 1856. The statue is the work of Joseph P. Pollia, and it shows

—Photo by Johnstown Tribune

MONUMENT TO PEARY

Peary in polar costume, with an Arctic dog running beside him. For the cost of the statue the children in the schools of Cresson and neighboring towns of Cambria County, Pa., contributed their pennies, and the grading and landscaping of the site, which is a dominating one in the fork of two great national highways, was done as a PWA project. At the back of the statue there is a stone hemicycle with benches for sitters, and a special parking place for cars has been prepared at the foot of the elevation.

Two thousand of the school children, led by their bands in uniform, marched in the procession which moved through the streets of the little town to the dedication ceremonies. Captain R. A. Bartlett, Peary's lieutenant, Matthew Henson, his Negro servant who stood with him at the Pole, and representatives of the Explorers Club, the National Geographic Society and the Geographical Society of Philadelphia were in attendance. The principal address was by Professor William H. Hobbs, of the University of Michigan, the biographer of Peary, and the statue was unveiled by Marie Peary Stafford and Peary Stafford, the daughter and the grandson of the great explorer.

Addresses were made on behalf of the citizens of the town, county and state by Attorney P. J. Little, of Ebensburg, and Chief Justice John W. Kephart, of the Supreme Court of Pennsylvania. The ceremonies of dedication were under the auspices of the Rotary Club of Cresson.

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